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PURPOSE OF THE INSTITUTE.

It is the purpose of the Institute, by means of conventions and publications, to increase and disseminate knowledge in regard to the use of cement, concrete and allied products; to conduct research into their properties and uses; and to formulate recommended practice and standard specifications.

Its objects are purely educational.

JOURNAL
OF
AMERICAN CONCRETE INSTITUTE

FOUNDED 1905, AND INCORPORATED 1906, AS
NATIONAL ASSOCIATION OF CEMENT USERS
CHARTER AMENDED JULY 2, 1913

The Institute is not responsible, as a body, for statements and opinions advanced in its publications

VOL. II FEBRUARY, 1914 NO 1

PROCEEDINGS.

The Proceedings of the Tenth Annual Convention will be published in Part II in the ensuing seven numbers of the JOURNAL which will be numbered serially, and on completion there will be furnished to the members, the table of contents and the usual prefatory information heretofore found in the annual volume of Proceedings. The latter, together with the second part of the seven numbers of the JOURNAL, may be bound together to form a complete volume of Proceedings.

Unless special request is made no bound volumes of Proceedings will be sent, as it will be assumed that subscribers to the Proceedings desire the JOURNAL in lieu of an annual volume. The matter is optional; to receive both the JOURNAL and the annual volume an additional payment is necessary. Those who wish the annual volume should communicate immediately with the Secretary.

The request for the right of publication of any report, paper, and other communication to the Institute must be made to the Secretary who will furnish an authorized abstract; under no condition will the publication of the complete report, paper, or communication be permitted. The privilege of the free publication of any matter presented to the Institute will not be hereafter extended to any one. This is done solely for the purpose of increasing the value of membership in the Institute and of its publications.

Institute Notes.

Standards Adopted by the Institute.

1. Standard Specifications for Cement with Appendix on Standard Methods of Testing and Chemical Analysis, 23 pp.
2. Standard Specifications for Portland Cement Sidewalks, 6 pp.
4. Standard Building Regulations for the Use of Reinforced Concrete, 13 pp.
5. Standard Specifications for One Course Concrete Highway, 10 pp.
6. Standard Specifications for Portland Cement Curb and Gutter, 7 pp.
7. Standard Recommended Practice for the Use of Reinforced Concrete, 21 pp.
8. Standard Specifications for Scrubbed Concrete Surfaces, 3 pp.
9. Standard Recommended Practice for Concrete Drain Tile, 3 pp.
10. Standard Recommended Practice for Concrete Architectural Stone, Building Block and Brick, 4 pp.
11. Standard Specifications for Concrete Architectural Stone, Building Block and Brick, 3 pp.
12. Standard Building Regulations for the Use of Concrete Architectural Stone, Building Block and Brick, 3 pp.
13. Standard Specifications for Plain Concrete Floors, 6 pp.
14. Standard Specifications for Reinforced Concrete Floors, 5 pp.
15. Standard Specifications for Portland Cement Stucco on Metal Lath, Brick, Tile or Concrete Block, 9 pp.
16. Standard Methods for the Measurement of Concrete Work, 7 pp.
17. Standard Specifications for One Course Concrete Street Pavement, 10 pp.
18. Standard Specifications for Two Course Concrete Street Pavement, 11 pp.

The above Standards can be obtained at the price of 25 cents each or in lots of ten or more at 20 cents each. Special price to Members 15 cents each or 10 cents each in lots of ten.

Reduced Price for Back Volumes.

Members of the Institute can obtain copies of back publications at the following special prices:

Vol. I, 50 cents; Vols. II to VI, $1.50 each; all in paper binding. For cloth or half morocco binding there is an additional charge per volume of 50 cents or $1.00 respectively. Vol. VII is available only in cloth binding, $2.00, or half morocco, $2.50.

Synopses of Recent Articles on Concrete.

Reviewed January 1 to 31, 1914.

The synopses given below are for the purpose of keeping the members of the Institute in touch with the leading articles of interest appearing in the many technical journals and are not complete reviews of these journals. The publications regularly reviewed appear below and the number given corresponds to the number following the title of the paper. The length of the article in pages, whether illustrated or not, is noted, and the publications reviewed in which it appears:

1. Canadian Engineer, Toronto, Ontario, Canada.
2. Cement, New York, N. Y.
3. Cement and Engineering News, Chicago, Ill.
4. Cement Era, Chicago, Ill.
5. Cement World, Chicago, Ill.
6. Concrete Age, Atlanta, Ga.
7. Concrete Era, Los Angeles, Cal.
8. Concrete-Cement Age, Detroit, Mich.
9. Concrete and Constructional Engineering, London, England.
10. Engineering and Contracting, Chicago, Ill.
11. Engineering News, New York, N. Y.
12. Engineering Record, New York, N. Y.
13. Good Roads Magazine, New York, N. Y.
14. Portland Cement, Kansas City, Mo.
15. Rock Products, Chicago, Ill.
16. Proceedings American Railway Engineering Association, Chicago, Ill.
17. Western Contractor, Record Building, Kansas City, Mo.
18. Journal National Fire Protection Association, Boston, Mass.
19. Journal Western Society of Engineers, Chicago, Ill.
20. Proceedings American Society of Civil Engineers, New York, N. Y.
21. Proceedings American Society of Municipal Improvements, New York.
22. Proceedings American Society for Testing Materials, Philadelphia, Pa.
23. Proceedings Engineers' Club of Philadelphia, Philadelphia, Pa.
24. Proceedings Engineers' Society of Western Pennsylvania, Pittsburgh, Pa.
25. Professional Memoirs, Corps of Engrs., U. S. A., Washington, D. C.
26. Proceedings Institution of Civil Engineers, London, England.
27. Transactions, Canadian Society of Civil Engineers, Montreal, Quebec, Canada.
28. Railway Age Gazette, Chicago, Ill.
29. Better Roads, Jamestown, Ohio.

MATERIALS

Variations in Results with Standard Cement Sieves. (11) Feb. 7, ¼ p.; (1) Feb. 12, 2½ pp.; (9) Feb. 25, ½ pp. Resumé of Technologic Paper 29, U.S. Bureau of Standards.

Need for Testing Commercial Sands for Use in Concrete. (11) Feb. 7, ½ p. Abstract of Paper by H. H. Schofield giving conclusions from tests.

The Testing of Sand for Use in Concrete—1. Field and Laboratory Practice, by Cloyd M. Chapman. (10) Feb. 5, 5 pp. ill. Methods of making tests, securing samples, etc., and results of tests.

Patent on the Autoclave Test. (11) Feb. 14, ⅔ pp.; (10) Feb. 19, 1 p. Text of patent.

Measurement of Gravel in Piles, by Oliver Clark. (10) Feb. 26, 1 p. Method of determining quantity of material.

Notes on Sandstone and Gravel for Salt Water Cement, by H. S. Taft. (1) Feb. 19, 4 pp. Discussion on tests of cement and aggregates for use in sea water.

Some Fallacies in Cement Testing, by W. L. Gadd. (8) Feb., 9 pp. Discussion of tests for cement.

DESIGN AND TESTS

Reinforced Concrete Footing Design for Columns. (11) Feb. 14, 1 p. ill. Diagrams for designing footings for various loads and bearing values of soil.

Testing Reinforced Concrete Poles (11) Feb. 14, 1 p. ill.; (3) Feb., 1 p. ill. Results of tests of full size hollow and solid poles broken by cable fastened at top.

Spirally Hooped Concrete Columns. (10) Feb. 19, ½ p.; (11) Feb. 21, ⅔ p. ill. Comparison of building code requirements of 20 cities for spirally hooped columns.

Reinforced Concrete Columns; Some Considerations Affecting their Design. (9) Feb. 11, 1½ pp. ill. Discussion of essential factors and comparison of building code requirements of 20 cities.

A Simplified Proof of the Three Moment Formula for Continuous Beams, by E. S. Slocum. (10) Feb. 19, 2½ pp. ill.

Approximate Stresses Produced by a Concentrated Load on a Continuous Slab Supported on Earth or other Yielding Foundation, by J. W. Pearl. (9) Feb. 11, 22 pp. ill. Theoretical discussion applicable to concrete pavement design and flat slabs supported on columns.

What is the Best Ratio of Steel to Concrete in Reinforced Concrete Beams and Slabs from the Cost Point of View, by R. F. Mirza. (8) Feb., 10 pp. Theoretical discussion of the most economical ratio of steel to concrete.

Report on a Series of Tests on Concrete Columns Reinforced with a Spiral of Steel by C. G. Wrentmore, H. Brodie and C. O. Carey. (19) Feb., 44 pp. ill.

HOMES

The Use of Concrete in the Construction of a Water Garden. (7) Feb., 4 pp. Method of using concrete for artificial pools and runways for small or large gardens.

Pergolas with Classic Pillars. (4) Feb., 3 pp. ill. Artistic concrete pillars for city or country home.

Modern Concrete Porches, by Jack Desmond. (4) Feb., 3 pp. Illustrated examples of porch design for bungalows.

Characteristics of Concrete Design, by Chas. E. White, Jr. (3) Feb., 4 pp. ill. Discussion of artistic design with illustrations.

BUILDINGS

Seventeen Acre Addition to an Industrial Plant in Detroit, Mich. (11) Feb. 14, 2 pp. Design and construction of building 202 ft. wide by 840 ft. long and six stories high with flat slab floors and 40 ft. craneway the floor length and height of the building for Ford Motor Co.

New Method of Centering Concrete in Building Work, by W. P. Anderson. (11) Feb. 14, 1 p. ill. Use of light metal decking on a matting formed of wooden strips attached to light metal chains which can be rolled in a bundle.

Cost Chart for Reinforced Concrete Factory Building. (11) Feb. 14, ½ pp. ill. Diagram showing distribution of cost for various items entering into construction of building.

Electric Railway Car House. (11) Feb. 14, 2 pp. ill. Design and construction of one story reinforced concrete car house 200 x 390 ft. and 36 ft. high.

Mandatory Fireproof Construction and the Economy of Concrete, by J. P. H. Perry. (7) Feb., 3 pp. ill. Discussion of effects of New York State Labor Law requiring fireproof construction for factories over 4 stories.

Using Steam to Heat and Cure Double Walls in Cold Weather. (7) Feb., 1 p. ill. (3) Feb., ⅔ p. ill. Method of constructing double wall milk station with temperature as low as 20° F.

Reinforced Concrete in the New Offices for the Board of Agriculture and Fisheries. (8) Feb., 8 pp. ill. Design and construction of concrete work on building 150 x 136 ft. and 95 ft. high.

BRIDGES AND RAILROAD WORK

Driving and Lining Point Defiance Tunnel. (11) Feb. 7, 1 p. ill. Design and construction of concrete tunnel 28 ft. diameter, 4391 ft. long.

Design and Cost of Ornamental Arch Bridges in Los Angeles, by A. W. Stewart. (11) Feb. 14, 2 pp. ill. Description of concrete arch bridges ranging from 200 to 968 ft. in length having spans from 58 to 119 ft. Temperature variation in arches during 2 years from self-registering thermometers.

Reinforced Concrete Columns for Bridges over St. Croix River at Hudson, Wis. (11) Feb. 14, 1½ pp. ill. Steel trusses on pairs of braced concrete piers 4 to 5 ft. diameter and 60 ft. high. Design and construction.

Schuylkill River Railroad Bridge. (11) Feb. 14, 2 pp. ill. Construction of nine double track concrete spans 800 ft. long, maximum span 103 ft.

Standard Concrete Piles for Bridge Foundation. (11) Feb. 14, ⅓ p. ill. Description of standard design adopted by C. B. & Q. R. R.

Building a Concrete Bridge in Halves. (11) Feb 21, 2 pp. ill. Design and construction of four track arches 115 ft. span at Baltimore without interrupting railroad traffic. The viaduct is 580 ft. long with a maximum height of 97 ft.

Utica Passenger Station Subways. (11) Feb. 28, 1 p. ill. Description of main concourse and subway passages for passengers and trucks.

Moving 300-Ton Bridge Pier. (11) Feb. 28, ⅔ p. ill. Description of moving concrete pier 60 ft. to new site.

Improvements of Louisville and Nashville Railroad. (10) Feb. 5, 5 pp. ill., Feb. 26, 7½ pp. ill. Improvements on 200 miles of roadway including reinforced concrete highway bridges and four tunnels.

Reinforced Concrete Girder and Slab Bridge with Pre-cast Members. (10) Feb. 5, 2½ pp. ill. Design and construction of reinforced concrete highway bridge 1075 ft. long and tunnels, bridges and culverts.

Reinforced Concrete Retaining Wall of Pedestal Construction, by E. G. Kaufman. (10) Feb. 5, 1¼ pp. ill. Analysis of design of retaining wall 110 ft. in length on each side of a bridge.

Highway and Street Railway Tunnels in San Francisco, by L. E. Torry. (10) Feb. 12, 1½ pp. ill. Design and description of one highway tunnel 50 ft. clear span and two street railway tunnels 13,000 ft. long providing for two tracks and two sidewalks.

Murray Avenue Concrete Arch, Pittsburgh. (10) Feb. 19, ½ p. ill. Construction progress on 210 ft. arch bridge.

Recommendations for Reinforced Concrete Highway Bridges and Culverts. (10) Feb. 26, 1¼ pp. Report of Committee of American Concrete Institute.

BRIDGES AND RAILROAD WORK

Grade Separation in McKees Rocks, Pa. (27) Feb. 27, 1½ pp. ill. Description of massive concrete retaining walls and concrete piles together with costs.

Method of Constructing a Short Rock Tunnel, by L. J. Putnam. (9) Feb. 4, 4 pp. ill. Design and construction of tunnel 29 ft. clear for two tracks, 1295 ft. long, cut through sandstone.

Design and Construction of the Bush and Gunpowder River Bridges, Consisting of a Series of Reinforced Concrete Slab Spans. (9) Feb. 11, 4 pp. ill. Bush River Bridge 2751 ft. and Gun Powder River Bridge 4961 ft. long; width 30 ft.

Design Features of the Reinforced Concrete Viaduct on Hopple Street, Cincinnati, O. (9) Feb. 11, 2 pp. ill.; (9) Feb. 25, 2½ pp. ill. Total length 1890 ft., consisting of 25 open skew spans, 65 to 80 ft. long. Details of super structure.

Methods of Concrete Construction in Track Elevation Work at Cleveland, O. (9) Feb. 18, 1 p. ill. Description of work involving 63,000 cu. yds. of concrete on 5 miles of track elevation.

A Discussion of the Advantages and Disadvantages of Fixed and 3-Hinged Concrete Arches. (9) Feb. 25, 3 pp.

Concrete Bridge in Southern California, by A. Marple. (4) Feb., 3 pp. ill. Design and construction of Colorado Street Viaduct at Pasadena. 1468 ft. long, 38 ft. wide and 167 ft. above water flow. Consists of 15 arches 113 to 223 ft. span.

Concrete Stations on the Lackawanna. (3) Feb., 3 pp. ill. General description of three concrete stations and platforms on the D. L. & W.

RESERVOIRS, DAMS, CANALS, ETC.

Horseshoe Falls Hydroelectric Plant, by Harold S. Johnston. (11) Feb. 7, 3 pp. ill. Description of 19,500 H. P. plant with concrete dam.

Construction of Ohio River Lock and Dam 12. (11) Feb. 7, 1⅔ pp. ill. Description of concrete structures on pile foundations. Dam 1120 ft. long.

Failure of Horse Creek Dam in Colorado. (11) Feb. 14, 4 pp. ill. Report on and cause of failure of earth filled dam with concrete face slabs.

Laying out New Water Supply System for Victoria, B. C. (11) Feb. 21, 3 pp. ill. Description of 27 mile gravity-flow concrete pipe and dam 455 ft. long with concrete core wall.

Reinforcing Ruptured Concrete Lining in High Pressure Aqueduct Tunnel, by John P. Hogan. (11) Feb. 28, 3½ pp. ill. Method of stopping leakage in Rondout Syphon of Catskill Aqueduct with welded steel rings encased in concrete.

Power Development at Saxon Falls, by C. A. Alderman. (11) Feb. 28, 2 pp. ill. Description of 190 ft. arch concrete dam 30 ft. high.

The Silver Lake Reservoir of the Catskill Water Supply System, by O. L. Brodie. (10) Feb. 5, 4 pp. ill. Description of reservoir, 3 reinforced concrete 48-in. conduits, 5800 ft. long and 4 ft. and 2 ft. 6 in. concrete pressure tunnel.

Reinforced Concrete Sheet Pile Sea Wall. (10) Feb. 5, 1 p. ill. Description of sea wall 9500 ft. long.

Construction Work for East St. Louis Flood Protection. (10) Feb. 5, 5 pp. ill. Description of concrete wall levee concrete tunnels, levee with reinforced concrete apron, etc.

The Injection of Cement Grout into Water Bearing Fissures, by Francis Donaldson. (10) Feb. 5, 1 p. Abstract of paper on grouting Rondout Syphon to stop flow of 1500 gallons per minute.

New Water Works Intake Tunnel and Tower for St. Louis, Mo. (10) Feb. 12, 4 pp. ill. Design of proposed tunnel 3100 ft. long and tower 150 ft. high.

Syphon Shillways on the Glens Falls Feature, New York State Barge Canal, by G. S. Stickney. (10) Feb. 12, 2 pp. ill. Design and construction of spillway 16 ft. wide.

Hollow Concrete Dam for Coatesville Water Works. (10) Feb. 26, 1 p. ill. Proposed design of dam 400 ft. long and 35 ft. high.

The Proposed Rock Run Storage Dam for the Additional Water Supply of Coatesville, Pa. (9) Feb. 11, 2 pp. ill. Design of dam 306 ft. long with concrete core wall earth embankments at ends.

Some Features of the Design and Construction of Twelve Million Gallon Water Filtration Plant at Evanston, Ill. (9) Feb. 4, 2 pp. ill. Basins and reservoirs of reinforced concrete.

Construction Features of the Intake Dam of the Tallulah Falls Development of the Georgia Railway and Power Company. (9) Feb. 18, 3 pp. ill. Gravity section dam, 316 ft. long and 115 ft. high.

Structural Features of an Interesting Small Hydroelectro Power Plant on the Sandusky River at Ballville, O. (9) Feb. 18, 2½ pp. ill. Details of design of solid concrete dam 285 ft. long, 41 ft. high and a one million gallon concrete reservoir 39 ft. high.

Field Notes on the Construction of a Great Concrete Standpipe by Allen D. Whipple. (7) Feb., 6 pp. ill. Construction of reinforced concrete standpipe 40 ft. diameter and 100 ft. high.

Efficient Plan for Building Locks on Ship Canal, by A. L. Erickson. (3) Feb., 4 pp. ill. Description of construction plant of locks for Lake Washington, Puget Sound Ship Canal.

Large Concrete Reservoir in St. Louis (Anheuser-Busch). (3) Feb., 3 pp. ill. Details of Design and Construction.

The Hudson River Crossing of the Catskill Aqueduct, by R. N. Wheeler. (22) Jan., 32 pp. ill. Construction of concrete lining and grouting of tunnel as well as shaft lining.

Reinforced Concrete in Municipal Engineering Works in San Francisco. (8) Feb., 7 pp. ill. Description of concrete work for sewers, reservoirs, pumping station, etc., at San Francisco.

Concrete and Reinforced Concrete at the Hydro-Electric Works, Chester, Eng. (8) Feb., 6 pp. ill. Design and construction of power house, drafting tubes, tail race, etc.

A Reinforced Concrete Wharf with Grouted Foundation at Iloilo, Philippines. (8) Feb., 9 pp. ill. Description of harbor improvements, method of grouting and construction of wharf.

Reinforced Concrete Gas Holder Tank at Hamburg. (8) Feb., 2 pp. ill. General description of gas holder tank 180 ft. diameter.

ROADS AND PAVEMENTS

Standards of Concrete Road Construction. (11) Feb. 21, 3 pp. Resumé of Committee reports presented at National Conference on Concrete Road Building.

Recommendations for Concrete Road Building. (11) Feb. 28, ⅛ p. Principles advocated by National Conference on Concrete Road Building and recommending the Standard Specifications of the American Concrete Institute.

Contraction and Expansion of Concrete Roads. (11) Feb. 28, 1 p. Summary of Committee report presented to National Conference on Concrete Road Building.

Patches in Concrete Pavements. (11) Feb. 28, ⅛ p. Patches in pavements are covered with ½ in. layer of asphalt for 2 or 3 weeks. Method gives excellent results.

Concrete in Road Construction. (11) Feb. 28, 2½ pp. Abstracts of papers read at National Conference on Concrete Road Building.

Concerning Concrete Roads. (10) Feb. 12, 2 pp. Editorial on National Conference on Concrete Road Construction.

A Concrete Road at La Salle, Ill., by A. H Hunter. (10) Feb. 19, 1 p. Description of 20 ft. roadway having grades up to 6 per cent.

Reports of the National Conference on Concrete Road Building. (10) Feb. 19, 2 pp., Feb. 26, 7 pp. Abstracts of papers presented at Conference.

Method and Cost of Constructing Concrete Road with Bituminous Wearing Surface in California. (9) Feb. 11, 7 pp. ill. Article gives data obtained from constructing road 14 miles long. Report forms for cost data.

Method and Cost of Constructing a Concrete Road with Concrete Line Poles and Concrete Fence at La Salle, Ill. (9) 1½ pp. ill. Details of cost and method of construction.

Cost of Constructing a Concrete Pavement Surfaced with Asphaltic Oil and Stone Screenings for Huntington Drive, Alhambra, Cal., by E. F. Eyres. (9) Feb. 18, 1½ pp. ill. Details of construction and cost for pavement about 2½ miles long.

Some Service Records of Bituminous Wearing Surface of Concrete Pavement. (9) Feb. 18, 1 p. ill. Record of surfacing on streets at Grand Haven, Mich.

Concrete Road Construction—a Symposium of Committee Reports to National Conference on Concrete Road Building. (9) Feb. 18, 3½ pp. Reports on repairing and maintenance, aggregates, handling of materials, mixing and placing, thickness of road and proportions and consistency of the concrete.

Investigation of the Causes of Expansion and Contraction of Concrete in Concrete Roads with Reference to the Prevention of Cracks. (9) Feb. 25, 4½ pp. ill. Investigation by Bureau of Standards reported to National Conference on Concrete Road Building.

Methods and Cost of Construction at Clinton, Iowa, Concrete Pavement with Bituminous Surface. (9) Feb. 25, 1 pp.

Road Maintenance Methods and Cost for Year 1913 in Wayne County, Mich. (7) Feb., 1½ pp. Report covers work on 51 miles of concrete roads and gives details of maintenance cost.

Cost of Concrete Pavement Iowa State College 1912 and 1913. (7) Feb., ¾ p. Details of cost of about 18,000 sq. yds. of concrete pavement.
Unusual Concrete Road near Philadelphia. (3) Feb., 2 pp. ill. General description of road 700 ft. long, 24 ft. wide. Details and cost.
Concrete Pavements in Connersville. (3) Feb., 1 p. ill. Description of 6 miles of concrete roads.
Concrete Roads. A Symposium. (3) Feb., 2 pp. Discussion at meeting of American Society of Civil Engineers.
First Concrete Road Conference. (14) Feb., 4 pp. Summary of Proceedings.
Concrete Roadways, by L. R. Ferguson. (22) Jan., 22 pp.; (7) Feb., 4 pp. Methods of construction and cost of various concrete roads.

SEWERS, PIPE, TILE, ETC.

Sewage Treatment at Sturgis, Mich. (11) 1 p. ill. Description covers treating plant with reinforced concrete settling tank 36 x 48 ft. and 8½ ft. deep.
Interbay District of Worth Trunk Sewer at Seattle. (11) Feb. 14, 2 pp. ill. Design and construction of concrete sewer 19 to 12 ft. diameter and 6190 ft. long, built largely in tunnel.
Concrete Sewer Pipe at Kansas City, Mo. (10) Feb. 12, ½ pp. Summary of paper by E. S. Wallace, Cement Inspector on use of concrete pipe in Kansas City.
Investigation of Concrete Drain Tile in Alkali Regions. (10) Feb. 26, 1 p. Program of proposed field investigations by a Committee of Government officials.
An Unusual Concrete Pipe Plant at Auburn, Wash. (27) Feb. 20, 2 pp. ill. Description of plant of Northern Pacific Railway Company for casting 24 and 26 in. reinforced concrete pipe, design and manufacture of which is given. Steam pipes inserted in forms to permit early stripping.
Methods and Cost of Construction Large Brick and Concrete Sewers in Chicago, with Wotes on the Cost Keeping System Employed. (9) Feb. 11, 4½ pp. ill. Details of design and construction together with itemized cost given.
Methods Employed in Making Reinforced Concrete Sewer Pipe in the Open during Freezing Weather at Louisville, Ky. (9) Feb. 25, ½ p. Manufacture of concrete pipe 24 to 57 ins. diameter during freezing weather.
Concrete in Drainage and Irrigation, by J. H. Libberton. (7) Feb., 2 pp. Discussion on the necessity of clean materials and dense mixtures and on affect of alkali.
Interstate Cement Tile Convention. (14) 2 pp. Summary of Chicago meeting.

CONCRETE PRODUCTS

Concrete Steel Fence Posts, by Wm. M. Stieve. (11) Feb. 14, 1½ pp. ill. Design construction and strength of fencing along Catskill Aqueduct.
Arrangement of Concrete Products Plants. (11) Feb. 28, 1 p. Summary of paper by E. S. Hanson containing recommendations for efficient layout of plant.
Matters of Design and Execution in Ornamental Concrete Products Manufacture. (7) Feb., 4 pp. ill. Designs and method of construction of vases, flower boxes, panels, etc.
Layout and Operation of Plant for Wet Process Block Manufacture using Metal Molds. (7) Feb., 6 pp. ill.; (4) Feb., 2 pp. ill. Description of Cast Stone plant at Detroit
Curing Cement Products by Steam. (4) Feb., 1 p. Methods of steam curing; capacity and dimensions of steam rooms.

MISCELLANEOUS

Decoration in Concrete Construction, by Paul Chesterton. (4) Feb., 5 pp. ill. Methods of producing different types of surface finish with four colored plates.
Fire Losses for 1913. (17) Jan., 4 pp. General summary of fire losses for the year.

AMERICAN CONCRETE INSTITUTE

PROCEEDINGS

OF THE

TENTH CONVENTION

This Institute is not responsible, as a body, for the statements and opinions advanced in its publications.

SUMMARY OF THE PROCEEDINGS OF THE TENTH ANNUAL CONVENTION.

FIRST SESSION—MONDAY, FEBRUARY 16, 1914, 8.00 P.M.

The Convention was called to order by President Richard L. Humphrey as follows:

It gives me great pleasure to open this, our Tenth Annual Convention, in the City of Chicago. It is interesting to note that since our organization as the National Association of Cement Users in Indianapolis nine years ago there has been great progress in the use of Portland cement. The uses of Portland cement have exceeded the most roseate dreams of those of us who were at the meeting in Indianapolis. There can be no question as to the value of the work this organization has done. It has established many standards, has stimulated a knowledge as to the use of cement itself, and the work it can do in the future is so great as to be limited only by its resources. The organization has tested full size structures and now has in progress in Pittsburgh tests of twenty-four full size columns, 20 in. in diameter and 12 ft. long. This is some of the work this Institute can do.

Attention is directed to the fact that the Institute enters upon the tenth year of its existence and the next convention will be the tenth anniversary.

We met in Chicago on our third and sixth conventions and the warmth of our reception, the attendance and all the other elements for which Chicago is famous, brought us back again. We invite every one in Chicago to participate in our discussions and give us the benefit of their judgment and experience while we impart ours.

It is with great pleasure that I introduce to you Mr. Henry Ericsson, Building Commissioner, City of Chicago, who will extend a welcome on behalf of the contracting interests.

Mr. Ericsson spoke as follows:

Mr. President and Gentlemen: I think it is safe to bid you all welcome, but as a past contractor and a possible contractor in the future, I hate to bid you welcome, because so many of you are contractors and of course we do not like to see so many come in all at once; we would like to have them come a little slower. But anyway, you are heartily welcome, I assure you of that.

I have been thinking of what to say, and tried to prepare myself, but did not succeed. The following by Longfellow, called "The Builders," may be appropriate on this occasion.

All are Architects of fate,
Working in these walls of time,
Some with massive deeds and great,
Some with ornaments of rhyme.

Nothing useless is, or low;
Each thing in its place is best;
And what seems but idle show
Strengthens and supports the rest.

For the structure that we raise;
Time is with materials filled;
Our todays and yesterdays.
Are the blocks with which we build.

Truly shape and fashion these;
Leave no yawning gaps between:
Think not, because no man sees,
Such things will remain unseen.

Build today, then, strong and sure,
With a firm and ample base,
And ascending and secure,
Shall tomorrow find its place.

Thus alone can we attain
To those turrets, where the eye
Sees the world as one vast plain,
And one boundless reach of sky.

Now this seems to apply a little to the concrete men. Let us build so it will last anyway till tomorrow.

In the city building department we inspect all plans of buildings and of course concrete construction comes under our eye also. Perhaps the most interesting development in reinforced concrete during the past year is flat slab construction. About two years ago representatives of various systems of flat slab construction applied for permits to use their systems in the City of Chicago. There were so many conflicting ideas on the subject, and so many extravagant claims made by some of the champions of patented systems of flat slab construction, that the Department decided that before permits were issued on any system, sufficient evidence should be furnished as to the strength of flat slab construction.

The applicant for a permit was required to present a report to the Department. In order to obtain data for these reports, a great many tests were made on buildings in the City. These tests were not the ordinary tests in which panels were merely tested by placing a load upon them, and noting the deflections, but were what are known as extensometer tests. In these tests panels were loaded and the actual stresses in the concrete and steel were obtained by an extensometer. This is a small instrument about 12 in. long. It is used to indicate the stretch in the steel, or the shortening in the concrete.

A great many points are taken in the test panels to determine the actual condition of affairs. It has been found that the stresses in the middle of the panel are considerably lower than those near the column.

A great many extensometer tests have been made; they are very costly, but bring out the actual condition of affairs in the slab. From these tests a vast amount of information has been obtained, so that this construction can now be safely designed. It can safely be said that in the City of Chicago more time and money and brains have been spent in investigating flat slab construction than in any other place, and that it is preeminently a leader in this type of construction.

It may be of interest to know how large panels have been built of this type of construction. On one job panels 24 x 25 ft. were built and tested at a load of 750 lb. per sq. ft. The maximum deflection was 5/16 in. On one panel alone on this job the test load was greater than the weight of the heaviest locomotive ever built. Other types of reinforced concrete are also used; a combination tile and concrete floor construction is used a great deal in hospitals. On one job built this year the clear span between supports of this type of construction was 38 ft.

As a general rule, reinforced concrete construction can compete on an even basis with heavy mill construction of timber. In some cases reinforced concrete construction is slightly less than mill construction. While the exact figures are not available, the City of Chicago undoubtedly leads in the volume of concrete construction done in all the great cities of the United States and Canada.

In conclusion permit me to welcome you on behalf of the city, if we can be of service to you during your visit I trust you will call on us.

President Humphrey:

Mr. Elmer C. Jensen, president, Illinois Chapter, American Institute of Architects, will welcome us on behalf of the architects. I take pleasure in introducing

Mr. Elmer C. Jensen:

Mr. President and Members of the American Concrete Institute: On behalf of the architects, it gives me more than pleasure to welcome this Institute to Chicago. All of us are very much interested in concrete, and I am quite sure that concrete is going to be the burden of many of your papers. For a number of years we have had the scare lines thrown into our office repeatedly, "Beware of Concrete! Beware of Concrete!" The race that has been on for the last three or four years has been very hot at times, and I can almost now, it seems to me, see concrete finishing first. At least, that is the way it looks to me at the present time. So many things have happened throughout the country that have been due to poor material, poor in many ways—probably poor cement, poor sand, poor stone, that it seems to me the time has arrived for this Institute to add one other element to concrete, namely, the one of sense. I think concrete should consist of cement, sand, aggregate, and then the fourth element, sense.

There is another thing that is necessary for such men as yourselves to do for the architects, and that is to develop and to devise suitable finishes for concrete and cement. Your attention is called to one particular piece of work in Chicago, and that is the railroad bridge of the Chicago Terminal Railway where it crosses the Central Park Avenue Boulevard. The manner in which it is finished, and withstands the weather, makes it in every way a very capable piece of work.

Concrete ought to be one of the noblest materials. True, it is a mixture of materials, but nevertheless it is a noble material if used in the right manner. It has been used most shamefully, and the time has arrived when we should use it intelligently. It is capable of use in different ways.

Why is it not possible to do things that have not yet been done? In that direction I am going to offer a suggestion, and that is that some of you experiment with making concrete under pressure. Some time ago I had occasion to see concrete that was made with pressure; and if you want material that has strength, at least the elements of strength that had, put concrete under pressure and try it.

Again, in behalf of the architects, I welcome you to the City, and hope you will add something to our available literature, particularly as to the finish of concrete.

President Humphrey:

There are many structures in Chicago which show architectural treatment. One of the things that the architects at least have to do for the concrete industry is to secure a design which is adaptable to concrete as a material in itself, not as an imitation of some of the other materials. I am glad Mr. Jensen has spoken about finish, as this is one of the phases of development in which the architect can lend no inconsiderable aid.

Mr. Finley is well known to you all, and I am sure he will be able to tell us of some of the points of interest in welcoming us to Chicago on behalf of the engineering interests. I take pleasure in introducing Mr. W. H. Finley, Chief Engineer of the Chicago and Northwestern Railway.

Mr. Finley spoke as follows:

Mr. President and Members of the Institute: I feel decidedly honored in being asked to welcome the American Concrete Institute on behalf of the engineers of Chicago. You are welcome, gentlemen, you are thrice welcome. I am going to tell you some of my own ideas and experience in concrete. We have reached such a stage that it is necessary to be rather plain-spoken about it.

It is just thirty-two years ago, I was quite a young man at that time, since I first saw concrete used, which was in an eastern city for a foundation in a train shed. I thought it queer looking stuff for a foundation, but just then along came the chief engineer who told me what it was. Eight years after that, or twenty-four years ago, I first had occasion to use concrete in my own work and have been using it since; however, in a conservative way. I believe sometimes, when I think of conservatism, I am very much in the same position as the rural gentleman who was elected to Congress. At that

time there was some important legislation pending and a newspaper man asked his attitude on this new legislation. "Well," he said, "back home about half the people think I am pretty smart; the other half think I am a fool. I am going to pursue the middle course." And I have pursued the middle course in the matter of concrete.

It has been my privilege to witness the change in construction material from wood to iron, from iron to steel, from stone to concrete. The company that I happen to be with at the present time is very conservative, fortunately situated as far as stone is concerned, and probably one of the last in the country to extensively use concrete. Today, owing to the rapid progress made in the production of cement, we are a concrete company. I remember when there was nothing but natural cement with the varying results obtained in construction work. A few years ago an abutment built of natural cement about twenty years ago, was taken down and it commanded my respect. We did not in the early days have the information and the knowledge of concrete of today. Some years ago I used some foreign cement, merely because the company serving us could not furnish the cement contracted for and instead delivered some English cement. Afterwards I had occasion, I regret to say, owing to the vicissitudes of engineering, to remove the back walls of the abutments. One was built of imported cement and the other of American Portland cement. I then and there got a very high opinion of American Portland cement and have had no occasion in the meantime to change my opinion. Today, in American Portland cement, we have the most uniform product of any of the materials used in construction work. Just so long as we confined ourselves to concrete, just plain concrete, designed as gravity sections, we were not far off from the proposition of stone; but suddenly there came into use reinforced concrete and this made an entire change in the method of design.

I have been rather conservative in the use of reinforced concrete. There is no closer analogy in the world than cast iron. It can be poured, as is cast iron; re-entrant angles are dangerous as with cast iron; it is subject to internal stresses the same as cast iron; it is a material that possesses very little tensile strength but a certain amount of compressive strength, just as cast iron.

In the early days of cast iron, before wrought iron or steel construction was very extensively used, all sorts of cast iron beams were designed, anticipating reinforced concrete. In the tension flange were imbedded wrought-iron rods to supply the tensile strength and develop the compressive strength of the cast iron. I am of the opinion that the only legitimate use of reinforcement is the imbedding of such an amount in the tensile flange of the beam as will produce the full compressive strength in the compression flange. Beyond that I believe you are going beyond the legitimate field of reinforced concrete. I have seen any amount of construction in this and other cities where it is not a question, in my opinion, of reinforced concrete but simply one of reinforced steel. I believe that if this practice continues it is going to result disastrously. I hate very much to be a prophet of evil, but that is the way I feel about too much reinforcement.

It is unfortunate that the commercial end has been pushed away beyond the engineering end. No matter how simple the question of concrete is today, it is still an engineering proposition. It cannot be successfully carried out without the aid and the experience of the trained engineer. Using the best cement in the world, the best cement that the United States turns out today, the most carefully graded aggregate and unless they are under the control of an experienced engineer the work is likely to result disastrously, as it has in a number of instances. I know you are all concrete men and that is why I am talking so plainly to you. I venture to say, gentlemen, there is no other form of construction where there has been an equal number of failures in the same space of time as in reinforced concrete. Trace each one of them back to the beginning and you will find it was simply due to the lack of intelligent engineering supervision.

I have seen the wooden Howe truss give way to the wrought-iron truss and the latter to the steel truss. I have seen the stone structure give way to the concrete structure and I have all the confidence in the world in the latter if its construction is properly supervised.

There is no question about the future use of cement or concrete. All I plead for is that it shall be under the supervision of trained and experienced men. There is not a failure but that when traced to its last analysis is found to be due to carelessness or incompetence. For that very reason you cannot get away from the fact, however good your cement, however closely graded your aggregate, you still require and it is vitally necessary that a trained and experienced engineer be in charge.

Years ago I happened to be in the contracting business and I say this to make good with the contractors here tonight, to let them know I have a fellow feeling. In the shadow of the Black Hills I saw concrete block being made with a machine that was sold by some eloquent and overpowering salesman, who persuaded that all they had to do was to buy this block machine and go anywhere and everywhere, with any old sort of material, and produce blocks and put up a building. I saw a building put up; it was a disgrace, a disgrace to concrete as a building material and it will so remain.

I was very much impressed with what Mr. Jensen said regarding the appearance of concrete. It is one of the things I have against concrete: it has not been used and treated architecturally. He did not say this as plainly as I, but not being an architect I have no hesitation. While there is no trouble in making concrete a pleasing construction, we must admit that in a great many cases it has not been done. It should be the duty of engineers and architects to lend their best efforts to not only make it an engineering construction but to make it a pleasing architectural construction.

PRESIDENT HUMPHREY:

I want to thank the speakers of the evening on behalf of the American Concrete Institute. They have given us much food for thought, and I am sure that all the architects and engineers in the City of Chicago will be only too glad to show the various structures in concrete and do all they can to make our stay here pleasant.

I am sure we cannot quite agree with all the statements that have been made of concrete. As a matter of fact reinforced concrete is a comparatively new material and I do not think it is fair to assume that we should in the course of a very few years be able to master all the fundamental principles of design affecting that material. The designing engineer in this country has not as yet reached the point where he uses reinforced concrete most efficiently. He does not think in terms of reinforced concrete, he thinks in terms of steel and other materials. You will bear in mind that at the time this organization was started in 1905, we did not have more than one building of reinforced concrete of any size, and since that time the buildings have sprung up all over the country; the next ten years will show even greater progress and that our present theories of design will look very crude and antiquated in comparison with the experience that we will gain.

It is particularly striking to a person who travels in Europe, especially in France, to see the treatment of structures of concrete,—graceful, beautiful structures, carrying great loads, meeting the artistic requirements that our friend Mr. Jensen has pointed out.

The French engineer has a truer conception of the principles of reinforced concrete design than we have; and I think that the spirit of skepticism which dominated concrete construction has been largely responsible for the types that we find which do not exactly conform to what we think they should be. I remember years ago the chief engineer of the Pennsylvania Railroad—and not so very long either—did not believe in concrete, and he used masonry, at a very much greater cost to his railroad, simply because he could not conceive that you could break up good stone and stick it together and obtain a mass of the strength you had originally; and the Pennsylvania Railroad for years used very little reinforced concrete. Today you will find the structures over the Big Muddy and Bush Rivers to be of concrete construction, and I think we owe the city of Chicago a great deal for that. The bridge over Broad Street and also the bridge across the Schuylkill River, which the Art Commission has passed, after five or six different designs had been submitted, are structures having an artistic merit that impresses you somewhat as the structures you see in Europe.

Our structures are entirely too massive and are overloaded by an excess use of material. Conservatism is a good thing and it is gratifying to see the design of structures of all kinds in the hands of those who are skilled.

We might consider for a moment the failures that have resulted from the use of other structural materials. There have been failures of structures in which cast iron, steel and other materials have been used, which have not reflected on the materials, because of the many examples of their successful use. In the early history of the cement industry there were many sidewalks laid which today would be condemned as bad construction; a bad sidewalk today brings discredit to the builder because there are so many excellent examples of good sidewalks, that no one now blames the material. The time is coming when the failure of a concrete building will not reflect on the material used but will reflect on the builder.

This Association is doing a great deal to bring about a more intelligent

and artistic use of concrete, and I trust that the engineers and architects in Chicago will join in the technical discussions of the next few days and cooperate with us in our endeavor to secure a better understanding of the principles of design for concrete and reinforced concrete.

On behalf of the members of this Association I thank you for the welcome that you have extended on behalf of the city, the engineers, the architects, and the contractors.

The President announced the following Committees appointed by the Board of Direction:

Committee on Nomination of Officers:

E. J. Mehren, *Chairman*, New York, N. Y.
Cloyd M. Chapman, New York, N. Y.
A. E. Lindau, Chicago, Ill.
L. T. Sunderland, Kansas City, Mo.
Sanford E. Thompson, Newton Highlands, Mass.

Committee on Resolutions:

Joshua L. Miner, *Chairman*, New York, N. Y.
E. S. Hanson, Chicago, Ill.
H. B. McMaster, Youngstown, O.
A. J. Maynard, State Farm, Mass.
W. A. Slater, Urbana, Ill.

The meeting then adjourned until Tuesday at 10.00 A.M.

SECOND SESSION—TUESDAY, FEBRUARY 17, 1914, 10.00 A.M.

President Richard L. Humphrey in the Chair.

The following papers were presented and discussed:

"Some Requirements in Vibrolithic Concrete Pavement Construction," R. C. Stubbs.

"Methods and Costs of Concrete Road Construction in Milwaukee County," H. J. Kuelling.

"Expansion and Construction of Concrete Roadways," Rudolph J. Wig.

The report of the Committee on Reinforced Concrete Highway Bridges and Culverts was then presented by the Chairman, Willis Whited, and discussed.

The meeting adjourned until 2.00 P.M.

THIRD SESSION—TUESDAY, FEBRUARY 17, 1914, 2.00 P.M.

President Richard L. Humphrey in the Chair.

C. W. Boynton, Chairman of the Committee on Concrete Roads and Pavements, submitted the report of the Committee, presenting:

"Proposed Standard Specifications for One Course Concrete Highways."

"Proposed Standard Specifications for One Course Concrete Street Pavement."

"Proposed Standard Specifications for Two Course Concrete Street Pavement."

These specifications were considered, amended and ordered to letter ballot of the Institute, except the paragraph on "Reinforcing," on which action was deferred until the next session.

The meeting then adjourned until 8.00 P.M.

FOURTH SESSION—TUESDAY, FEBRUARY 17, 1914, 8.00 P.M.

President Richard L. Humphrey in the chair.

The annual address of the President, "The Use of Concrete in Hydraulic Works," was delivered by Richard L. Humphrey,

Mr. B. S. Pease presented a paper on Reinforced Concrete Roadways and Pavements, which was discussed.

The paragraph on "Reinforcing" in the proposed Standard Specifications for Concrete Pavements, action on which was deferred at the afternoon session, was then presented by the Chairman of the Committee, C. W. Boynton. After discussion this paragraph was adopted in the amended form and referred as part of the Specifications to letter ballot.

The following papers were then presented:

"Progress and Development of Concrete Work on the Delaware, Lackawanna and Western Railroad," by A. B. Cohen.

"The Present Status of the Investigation of the Effect of Alkali on Cement Pipe," by R. J. Wig.

The meeting adjourned until Wednesday, 10.00 A.M.

WEDNESDAY, FEBRUARY 18, 1914, 9.00 A.M.

Meeting of the Section on Concrete Products.

President Humphrey opened the meeting and turned the chair over to C. K. Arp, Chairman of the Committee on Building Blocks and Concrete Products, for a general discussion on proportions, mixing and consistency for concrete tile and pipe.

FIFTH SESSION—WEDNESDAY, FEBRUARY 18, 1914, 10.00 A.M.

Joint Session with American Concrete Pipe Association.

Presidents Richard L. Humphrey and P. H. Atwood in the chair.

The report of the Committee on Building Blocks and Concrete Products was presented by the Chairman, C. K. Arp, and discussed.

The following papers were then read and discussed:

"Specifications for Drain Tile," by A. Marston.

"Results of Tests on Plain and Reinforced Concrete Tile," by George P. Dieckmann.

"Layout of Concrete Products Plants," by E. S. Hanson.

The meeting then adjourned until 8.00 P.M.

SIXTH SESSION—WEDNESDAY, FEBRUARY 18, 1914, 8.00 P.M.

President Richard L. Humphrey in the chair.

The following papers were presented and discussed:

"Modern Concrete Work without Forms," by J. E. Payne.

"The Properties of Portland Cement Containing a High Percentage of Magnesia," by P. H. Bates.

"Combination of Reinforcement and Forms in Concrete Construction," by T. W. Murray, in the absence of the author presented by A. I. Auten.

Mr. L. C. Wason read a report on the Condition of the Concrete Test Pieces Suspended in Boston Harbor, which was discussed.

Mr. C. D. MacArthur presented a paper on "Steel Forms in Concrete Construction," which was discussed.

Mr. L. C. Wason presented a paper on "The Problems of the Contractor."

The meeting then adjourned until Thursday, 10.00 A.M.

SEVENTH SESSION—THURSDAY, FEBRUARY 19, 1914, 10.00 A. M.

President Richard L. Humphrey in the Chair.

Business Session—The annual report of the Board of Direction was approved as read.

The Committee on Nomination of Officers, E. J. Mehren, Chairman, reported the following nominees for the offices vacant and the Secretary was instructed to cast a ballot for their unanimous election:

President—Richard L. Humphrey, Philadelphia, Pa.
Vice-President—Leonard C. Wason, Boston, Mass.
Directors—Second District, Edward D. Boyer, New York, N. Y. Third District, Robert W. Lesley, Philadelphia, Pa. Sixth District, John B. Leonard, San Francisco, Cal.
Treasurer—Robert A. Cummings, Pittsburgh, Pa.

President Humphrey, in accepting the presidency for the tenth time, stated that he would not under any condition accept a re-election. He believed that the president should be elected for one year and that he should not be eligible for re-election. He believed that during the year most of the difficulties that confronted the Institute would be met, and that further service on his part would be undesirable.

Invitations to hold the next Convention in their respective cities were extended by Mr. George C. Walters of Atlanta, Ga., and Mr. E. L. Hatfield of San Francisco, Cal.

The Secretary presented the proposed amendments to the By-Laws which were ordered to letter ballot.

The report of the Committee on Reinforced Concrete and Building Laws, Alfred E. Lindau, Chairman, was presented and discussed.

The report of the Committee on Nomenclature was presented by the Chairman, F. C. Wight.

Mr. Oliver Randolph Parry presented a discussion on the Artistic Treatment of Concrete Structures.

The following papers were then read and discussed:

"Full Sized Tests and their Value in Concrete Construction," by B. S. Brown.

"Test of a Reinforced Concrete Flat Slab Floor," by W. A. Slater.

The meeting adjourned until Friday, February 20, 10.00 A. M.

THURSDAY, FEBRUARY 19, 1914, 7.00 P. M.

The Annual Banquet of the Institute was held at the Auditorium Hotel.

President Richard L. Humphrey introduced the Toastmaster, Dr. Edwin Herbert Lewis, Dean of Lewis Institute, Chicago, Ill.

The speakers of the evening were:

Hon. Clarence Norton Goodwin,
Judge of the Circuit Court, Cook County, Ill.

Rev. James Samuel Stone, D.D.,
Rector of St. James' Episcopal Church, Chicago, Ill.

Dr. Henry Baird Favill,
Chairman of the Council on Health and Public Instruction, American Medical Association, Chicago, Ill.

EIGHTH SESSION—FRIDAY, FEBRUARY 20, 1914, 10.00 A.M.

President Richard L. Humphrey in the Chair.

The report of the Committee on Specifications and Methods of Tests for Concrete Materials was, in the absence of the Chairman, presented by A. N. Talbot, a member of the Committee, and was discussed.

The following papers were then read and discussed:

"Some Comparative Corrosion Tests of Plastered Metal Lath," J. C. Pearson; in the absence of the author read by Mr. H. B. McMaster.

"Data on Lime Putty and Cream of Lime," Cloyd M. Chapman.

The report of the Committee on Treatment of Concrete Surfaces was submitted by the Chairman, L. C. Wason, presenting

revisions in the Standard Specifications for Portland Cement Stucco which were discussed and action deferred until the next session.

The meeting then adjourned until 2 P.M.

NINTH SESSION—FRIDAY, FEBRUARY 20, 1914, 2 P.M.

President Richard L. Humphrey in the Chair.

After discussion the revision of the Specifications for Portland Cement Stucco on Metal Lath was ordered to letter ballot.

The proposed Specifications for Portland Cement Stucco on Wood Lath were presented by Cloyd M. Chapman and discussed, ordered printed and referred back to the Committee for further consideration.

The following papers were then presented and discussed:

"Post Molds and Manufacture of Reinforced Concrete Fence Posts," G. H. Dougherty.

"The Concrete Fence Post," A. M. Smith.

The paper on "Sanitary Surfaces for Concrete Floors," by T. Hugh Boorman, was in the absence of the author read by the Secretary.

The following resolutions were submitted by the Committee on Resolutions and unanimously adopted:

Resolved, That the thanks of this Association are hereby tendered the officials of Chicago and the representatives of the local Architectural Engineering and Concrete interests for their hearty welcome; to the press and citizens of Chicago for their co-operation in making this, the Tenth Annual Convention, a notable success and to the guests of the Association for their assistance in this success by the contribution of their interesting and valuable papers.

Resolved, That the thanks of this Association are hereby tendered to the members who have aided by the presentation of papers, to the several committees whose efforts have added this tenth meeting to the series of successful conventions; to the technical press whose recognition of and assistance in the work of this organization are gratefully acknowledged; and to its various officers but particularly to its president, Mr. Richard L. Humphrey, for their untiring devotion to the interest and welfare of this Association. The Institute also records its appreciation of the services of its retiring Treasurer, Mr. Henry H. Quimby, and the retiring Directors, Mr. Charles Derleth, Jr., and Mr. Ernest L. Ransome.

Resolved, That the Institute expresses its appreciation of the fact that the officers and Board of Direction have made it possible to begin the publication of a monthly Journal for the Institute, and recognizes that such a Journal can be of great value to the members and to the industry at large.

The President declared the Convention adjourned *sine die*.

ANNUAL REPORT OF THE BOARD OF DIRECTION.

The Board of Direction presents herewith the following report on the condition of the affairs of the Institute.

Meetings.—Since the last Convention the Board has held 3 meetings. An abstract of the Minutes of these meetings is appended.

Membership.—The membership included in the last report was 853. Since that time 74 new members have been added and 35 have been dropped for the non-payment of dues. The Board also records with deepest regret the loss by death of Robert Anderson and A. W. Paige.

The present membership is 891.

Report of the Treasurer.

Statement of Receipts and Expenditures for the Year ended June 30, 1913.

Receipts.

Balance, July 1, 1912			$1,132.63
Dues: 1911	$195.00		
1912	2,500.00		
1913	10.00		
Contributing Members	100.00		
		$2,805.00	
Publications: Sales	$522.00		
Advertisements	175.00		
Standards	265.00		
		962.00	
Conventions: Kansas City	$931.17		
Pittsburgh	1,034.65		
		1,965.82	
Membership Certificates		11.00	
Subscriptions		44.00	
Interest on Deposits		8.10	
Miscellaneous		8.09	
Total Receipts			5,804.01
			$6,936.64

EXPENDITURES.

Office: Postage	$238.27		
Supplies	68.27		
Printing	87.75		
Salaries	2,267.56		
Rent	720.00		
Bonds	40.00		
Telephone	102.00		
Telegrams	12.50		
Dues, N. F. P. A.	40.00		
Audit	60.00		
		$3,636.35	
Publications: Proceedings, Vol. VI	$604.60		
" " VII	376.22		
" " VIII	80.00		
Circulars	112.25		
List of Members	290.00		
Standards	197.25		
Express	11.45		
Storage	72.00		
Miscellaneous	13.55		
		1,757.32	
Executive Board		5.25	
Membership Certificate		1.05	
Subscriptions and Traveling Expenses		453.32	
Convention: Kansas City	$329.00		
Pittsburgh	443.84		
		772.84	
Exchange		3.99	
Committee		3.10	
Research Fund		65.00	
Interest		51.35	
Miscellaneous		92.75	
Total Expenditures		$6,842.32	
Balance, June 30, 1913		94.32	
			$6,936.64

NOTE.—Due for bills incurred and unpaid June 30, 1913:

John C. Winston Co	$3,069.35
Arthur W. Kelly	201.75
	$3,271.10

PHILADELPHIA, 13th February, 1914.

We hereby certify that we have audited the accounts of the Treasurer of the National Association of Cement Users for the year ended June 30, 1913, and found that the dues collected and receipts from the sales of publications, etc., as they appear on the cash-book have been properly accounted for and that all disbursements were substantiated by vouchers.

The foregoing report of the Treasurer is in agreement with the books of account.

(Signed) LYBRAND, ROSS BROS. & MONTGOMERY,
Certified Public Accountants.

Publications.—The Board of Direction has given most careful consideration to the question of the publications of the Institute. It is felt that the practice of issuing an annual volume of Proceedings of at least 700 pages each year, a number of months after the close of the Convention, is not as valuable to the members as to issue them serially. The Volume is too large to be conveniently carried and the great mass of material is not in as readable a form as a smaller volume would be. The Board believes the members will be better served through a monthly Journal which in addition to the papers and discussions at the Conventions, will also contain current items of interest concerning the activities of the Institute, as well as a review of the Technical literature and other matters. Three numbers of this JOURNAL have been issued, the first part of each containing the activities of the Institute and the second part the papers and discussions. These parts are each numbered consecutively and on completion of the papers presented at one Convention, can be bound together as a separate volume. The Board has deemed it desirable to include in the Journal a review of current technical literature and also providing a review of the current patents covering concrete and machinery and appliances for using the same and also of trade publications. The number of pages in the JOURNAL will be increased to 80, so that during the year the Proceedings of each Convention may be taken care of besides the publications of advance reports of Committees and other matters to come before the annual Convention.

The Board has been obliged to raise, through subscriptions, money to defray the back indebtedness on publications. The

Proceedings of the Kansas City Convention will be mailed to the members during the month of March. The Proceedings of the Pittsburgh Convention are being currently published in the JOURNAL. From the interest manifested, the Board is convinced that the JOURNAL fills a highly desired need in keeping the members in closer touch with the important work the Institute is doing.

Research Fund.—The Institute, as announced in the January number of the JOURNAL, has arranged a series of tests of 24 columns, 20 in. diameter and 12 ft. long, which we believe will give data of the greatest value. The activities of the Institute in this direction are limited by its resources and in this particular case the tests are made possible only through donations.

Change of Name.—In accordance with the expressed wishes of the Convention, the name of the organization was changed on July 2, 1913, to American Concrete Institute, by amending the Charter of the National Association of Cement Users granted in 1906.

The change has been favorably commended and we believe will increase the prestige and strength of the organization.

Convention.—The Board finds itself embarrassed each year with a great mass of papers and reports and it becomes a matter of great difficulty to limit the number to what can be reasonably considered during the Convention. This year the Board deliberately attempted to limit the number of papers but it was found necessary to increase this number. The experience of this Convention indicates that even this number is greater than can be conveniently read and discussed. The Board believes that by selecting the papers from those available and encouraging discussion, material of great value may be secured.

In this connection the Board wishes to announce the donation of Mr. Leonard C. Wason, our Vice-President, of a bronze medal to be offered annually for papers presented at the Convention. The details concerning the regulations governing the award and other matters pertaining thereto are now being considered by the Board and full announcement will be made in the JOURNAL. The Board in making this announcement wishes to express its appreciation of this evidence of the interest of Mr. Wason in the work of the Institute.

Income and Expenses.—The report of the Treasurer shows that the income of the Institute is considerably less than the current expenses and for the Institute to continue to perform the work it is doing there must be a large increase in membership or a substantial number of advertisements in the JOURNAL or contributions from other sources to make up this deficit. It was necessary, therefore, for the Board through its President, to raise through subscriptions about $6,000.00 to care for the accrued deficit.

The Board believes that with the increased activities of the Institute and through the service given by the JOURNAL that there will be a corresponding increase in the number of members and is actively considering ways and means by which the Institute can be made self-supporting. For this increase the active interest of each member in securing additional members, as has been repeatedly pointed out by the Board, is highly desirable and the Board repeats that it should be easy for each member to get at least one other member and more than double the present membership. The Board is the servant of the members of the Institute but it is unreasonable to expect it to perform duties that unquestionably belong to the members.

Conclusions.—The Board feels that the activities of the Institute are very much restricted through lack of resources and believes that a reasonable support would enable the Institute to perform work of the greatest value.

Abstract of Minutes of Meetings of the Board of Direction.

ABSTRACT MINUTES OF MEETING OF BOARD OF DIRECTION, JANUARY 15, 1913, 3 P. M., ROOMS OF THE AMERICAN SOCIETY FOR MECHANICAL ENGINEERS, NEW YORK, N. Y.

Present: Richard L. Humphrey, President; Arthur N. Talbot, Vice-President; Edward D. Boyer, Director, and Edward E. Krauss, Secretary.

The President reported the progress made in securing subscriptions to the $6,000.00 fund, and it was decided to call a meeting of the Board some time after March 1st to consider the finances of the Association and the publication of a Journal.

The matter of change of name was referred to President with power.

The resignation of the Treasurer, Henry C. Turner, was accepted with regret, to become effective as soon as his successor qualified.

ABSTRACT MINUTES OF MEETING OF BOARD OF DIRECTION, AUGUST 21, 1913, 2.40 P. M., HOUSE OF AMERICAN SOCIETY OF CIVIL ENGINEERS, NEW YORK, N. Y.

Present: Richard L. Humphrey, President; Leonard C. Wason, Vice-President; Benjamin F. Affleck, William P. Anderson, Edward D. Boyer, Ernest L. Ransome, Directors; Henry H. Quimby, Treasurer; and Edward E. Krauss, Secretary.

The minutes of meetings of Board of Direction held December 10, 11 and 16, 1912, and informal meeting of January 15, 1913, were approved.

The Secretary reported that the Board of Direction by letter ballot on January 29, 1913, unanimously approved the President's recommendation to change the name of the Association to the "American Concrete Institute."

The Secretary reported that the Board on February 12, 1913, had unanimously approved the election of Henry H. Quimby as Treasurer.

The Secretary presented the report of the Public Accountants on the cash balance which had been transferred by Henry C. Turner from the Bankers' Trust Company, New York, N. Y., to Henry H. Quimby, Treasurer, and deposited in the Franklin Trust Company, Philadelphia, Pa.

The Secretary reported that the ballot of Board of Direction April 17, 1913, unanimously approved holding 10th Convention in Chicago.

The Board approved the report of the Tellers on the letter ballot on the proposed new Standards canvassed June 1, 1913.

The Board considered the request for a modification of the proposed Standard Specifications for Portland Cement Stucco, and decided that it did not lie within its power to make any modifications in matters approved by the Institute by letter ballot, and the matter was referred to the Committee for report at the next Convention.

The Secretary reported 14 applications for membership which were unanimously elected. He also reported that the total membership at the

Pittsburgh Convention was 852; 33 members had since been added and 20 resigned, making total on August 21, 1913, of 865. Report was approved.

The Treasurer presented a statement of receipts and expenditures for the fiscal year ending June 30, 1913.

The Secretary presented budget for fiscal year ending June 30, 1914.

The President reported that he had collected in cash $5,450.00 of the $6,000.00 subscription fund, and that he felt sure of securing the remaining $550.00 during the year.

The President presented a proposition by Mr. Allen Brett on publishing a Journal of the Institute, and was directed to advise Mr. Brett that it was inexpedient to entertain his proposition.

The President and Secretary were directed to issue the Kansas City Proceedings immediately and a Journal of the Institute to contain such portions of the Pittsburgh Proceedings as they deemed expedient, to appear in October of present year, the entire Proceedings to be published within a year.

It was decided to publish 1,500 copies of Volume VIII of the Proceedings.

The President was directed to pay out of the subscription fund in his possession the bill of the John C. Winston Company for $3,069.35, covering the printing of Volume VII.

The President and Secretary were authorized to make such disposition of back numbers of the Proceedings as in their judgment was desirable, reserving 100 copies of each volume.

The President was authorized to complete all arrangements for the series of column tests to be made under the direction of the Committee on Reinforced Concrete in co-operation with the U. S. Bureau of Standards, the University of Illinois and the Turner Construction Company.

The Auditorium Hotel was selected as headquarters for the Tenth Annual Convention to be held in Chicago, February 16 to 20, 1914.

The President reported on status of he Trunk Lines Association suit.

The meeting adjourned at 7.06 P. M.

ABSTRACT MINUTES OF MEETING OF BOARD OF DIRECTION, DECEMBER 12, 1913, 10.35 A. M., HOUSE OF AMERICAN SOCIETY OF CIVIL ENGINEERS, NEW YORK, N. Y.

Present: Richard L. Humphrey, President; Leonard C. Wason, Vice-President; Benjamin F. Affleck and Edward D. Boyer, Directors; Henry H. Quimby, Treasurer; and Edward E. Krauss, Secretary.

The Board approved the minutes of the meeting of August 21, 1913.

The Treasurer presented a report on the receipts and expenditures from July 1st to December 10, 1913.

The Secretary reported that since July 1, 1913, 38 new members had been elected and 6 members had resigned. The total membership on December 12, 1913, was 884.

It was decided, beginning with the first issue after the Chicago Convention, Part II should be so printed that the several parts could be bound together as one volume by those desiring the Proceedings in bound form.

The following rates for advertisements in the JOURNAL were approved:

Full page	$180.00
Half page	100.00
One-quarter page	60.00
Back cover	250.00
Inside cover	200.00

The tentative program of the Chicago Convention, submitted by the President, was approved.

At the suggestion of the President, a Committee on Publicity with E. J. Mehren as Chairman, was approved.

Messrs. Benjamin F. Affleck and Edward D. Boyer were elected members of the Executive Committee.

The following revisions of the By-Laws were authorized:

Change "Association" to "Institute" wherever it occurs in the By-Laws.

ARTICLE II.

SECTION 3. Insert a new Section 3 to read as follows and renumber old sections 3–12 to 4–13.

SEC. 3 (new). There shall be a Committee of five members on Nomination of Officers, elected by letter ballot of the members of the Institute, which is to be canvassed by the Board of Direction on or before September 1st of each year.

The Committee on Nomination of Officers shall select by letter ballot of its members, candidates for the various offices to become vacant at the next Annual Convention and report the result to the Board of Direction who shall transmit the same to the members of the Institute at least 60 days prior to the Annual Convention. Upon petition signed by at least ten members, additional nominations may be made within 20 days thereafter. The consent of all candidates must be obtained before nomination. The complete list of candidates thus nominated shall be submitted 30 days before the Annual Convention to the members of the Institute for letter ballot, to be canvassed at 12 o'clock noon on the second day of the Convention and the result shall be announced the next day at a business session.

SEC. 4. Amend by striking out the words "appoint the Secretary" and insert the following:

"Have general supervision of the affairs of the Institute and at the first meeting following its election, appoint a Secretary and from its own members a Finance Committee of three."

SEC. 5. Strike out the present wording and substitute the following:

"It shall be the duty of the Finance Committee to prepare the annual budget and to pass on proposed expenditures before their submission to the Board of Direction. The accounts of the Secretary and Treasurer shall be audited annually."

SEC. 6. Strike out words—

"A Committee on Nomination of Officers and."

SEC. 9. Revise first sentence to read—

"The President shall perform the usual duties of the office."

SEC. 10. Revise to read—

"The Secretary shall be the general business agent of the Institute, shall perform such duties and shall furnish such bond as may be determined by the Board of Direction."

ARTICLE III.

SEC. 2. Amend by striking out the words—"immediately after" and substitute "during," and strike out the words "was" and substitute "is."

The Institute adopted the following statement of its purpose:

"It is the purpose of the Institute by means of Conventions and publications to increase and disseminate knowledge in regard to any use of cement, concrete and allied products; to conduct research into their properties and uses; also to formulate and recommend standard specifications for their use. Its objects are purely educational."

Permission was granted to Mr. Allen to reprint the report on Standard Methods for Measuring Concrete, subject to the usual credit to the Institute.

The President reported the result of his conference with the attorney of the Trunk Lines Association, and that it was their intention to endeavor to collect from each individual certificate holder.

The following Committee on Nomination of Officers was appointed:

E. J. Mehren, Chairman, New York, N. Y.
Cloyd M. Chapman, New York, N. Y.
A. E. Lindau, Chicago, Ill.
L. T. Sunderland, Kansas City, Mo.
Sanford E. Thompson, Newton Highlands, Mass.

The Board appointed the following Finance Committee:

L. C. Wason,
Henry H. Quimby,
Edward D. Boyer.

The meeting adjourned at 2.40 P. M.

ABSTRACT MINUTES OF MEETING OF BOARD OF DIRECTION, FEBRUARY 16, 1914, 5 P. M., AUDITORIUM HOTEL, CHICAGO, ILL.

Present: Richard L. Humphrey, President; Leonard C. Wason, Vice-President; Benjamin F. Affleck, William P. Anderson, Edward D. Boyer, Directors; and Edward E. Krauss, Secretary.

The Board appointed the following Committee on Resolutions:

Joshua L. Miner, Chairman, New York, N. Y.
E. S. Hanson, Chicago, Ill.
H. B. McMaster, Youngstown, O.
A. J. Maynard, State Farm, Mass.
W. A. Slater, Urbana, Ill.

ABSTRACT MINUTES OF MEETING OF BOARD OF DIRECTION, FEBRUARY 18, 1914, 5 P. M., AUDITORIUM HOTEL, CHICAGO, ILL.

Present: Richard L. Humphrey, President; Leonard C. Wason, Vice-President; Benjamin F. Affleck, William P. Anderson, Edward D. Boyer, Directors; and Edward E. Krauss, Secretary.

The Finance Committee presented a report which was received.

The President announced the donation by Mr. Leonard C. Wason of a Medal to be awarded for the best paper presented at an Annual Convention. The Board accepted this generous offer, and decided to appoint a Committee on Medals to report on the conditions governing the acceptance of the Medal, and the method of making the award.

ABSTRACT MINUTES OF MEETING OF BOARD OF DIRECTION, FEBRUARY 19, 1914, 9.45 A. M. AUDITORIUM HOTEL, CHICAGO, ILL.

Present: Richard L. Humphrey, President; Arthur N. Talbot, Vice-President; Benjamin F. Affleck, William P. Anderson, Edward D. Boyer, Directors; and Edward E. Krauss, Secretary.

The President submitted the Annual Report of the Board, which with some amendments, was approved.

132 total

Register of Attendance—Tenth Convention

Richard L. Humphrey, Philadelphia, Pa.
Arthur N. Talbot, Urbana, Ill.
Leonard C. Wason, Boston, Mass.
Benjamin F. Affleck, Chicago, Ill.
William P. Anderson, Cincinnati, Ohio.
Edward D. Boyer, New York, N. Y.
W. L. Church, Boston, Mass.
Charles Derleth, Jr., Berkeley, Cal.
E. L. Ransome, New York, N. Y.
Henry H. Quimby, Philadelphia, Pa.
Edward E. Krauss, Philadelphia, Pa.

Arp, C. K., Chicago, Ill.
Atwood, P. H., Armstrong, Iowa.
Abrams, Duff A., Chicago, Ill.

Boynton, C. W., Chicago, Ill.
Barry, David, Ottawa, Canada.
Brett, Allen, Chicago, Ill.
Barndt, J. W., Garnett, Kan.
Beck, J. P., Chicago, Ill.
Battjes, N. H., Grand Rapids, Mich.
Bates, P. H., Pittsburgh, Pa.
Bramin, Addison, Aberdeen, Miss.
Balyeat, Luman, Van Wert, Ohio.
Brown, B. S., Boston, Mass.
Bingham, L. L., Estherville, Iowa.

Chubb, J. H., Chicago, Ill.
Comoli, P. P., Sioux City, Iowa.
Cromar, A. J., Ontario, Canada.
Christian, H. A., Palmerton, Pa.
Cohen, A. B., Hoboken, N. J.
Collings, W. A., Kansas City, Mo.
Condron, T. L., Chicago, Ill.
Chain Belt Co., Milwaukee, Wis.
Chapman, C. M., New York, N. Y.
Corrugated Bar, Chicago, Ill.

Doyle, H. S., Chicago, Ill.
De Haas, N. G., Marquette, Mich.
Dougherty, G. H.
Dieckman, G. P., Mason City, Iowa.

Ewing, Davis, Bloomington, Ill.
Eureka Machine Co., Lansing, Mich.

Ferguson, Lewis R., Philadelphia, Pa.
Freeman, J. E., Chicago, Ill.
Fraser, N. D., Chicago, Ill.
Foote, H. W., Chicago, Ill.

Greisnauer, M. K., Chicago, Ill.

Hall, R. F., Chicago, Ill.
Hanson, E. S., Chicago, Ill.
Heller, C., San Francisco, Cal.
Harridge, J. K., Chicago, Ill.
Hackedorn, H. F., Indianapolis, Ind.
Harding, William H., Philadelphia, Pa.

Irvine, F. K., Chicago, Ill.
Isenberg, Gerson, New York, N. Y.
Illinois Steel Co., Chicago, Ill.

Johnson, A. S., Long Island, N. Y.

Kinney, William M., Chicago, Ill.
Kerr, H. D., New York, N. Y.
Kline, A. E., Chicago, Ill.
Knickerbocker Co., Jackson, Mich.

Lindau, A. E., Chicago, Ill.
Lester, A. V., Chicago, Ill.
Low, Robert S., Ottawa, Canada.
Larned, E. S., Boston, Mass.
Light, Chas. P., Washington, D. C
Libberton, J. H., Chicago, Ill.

Miner, J. L., New York, N. Y.
Miller, R. T., Pittsburgh, Pa.
Maynard, A. J., State Farm, Mass.
Mensch, L. J., Chicago, Ill.
Metzger, F. L., Pittsburgh, Pa.—Cummings Structural Concrete Co.
Metzger, F. L., Pittsburgh, Pa.—Electric Welding Co.
Mehren, E. J., New York, N. Y.
Moore, E. J., Dallas, Texas.
McMaster, H. B., Youngstown, Ohio.
McArthur, C. D., Chicago, Ill.
McKay, Stewart, Chicago, Ill.
Meyer, C. L., New York, N. Y.
Milwaukee Concrete & Mixer Machine Co., Milwaukee, Wis.

New Way Motor Co., Lansing, Mich.

Perry, J. P. H., New York, N. Y.
Pease, B. S., Chicago, Ill.
Powers, E. L., Chicago, Ill.
Parry, O. R., Philadelphia, Pa.
Payne, J. E., Mansfield, Ohio.
Potter, Jr, N. S., Chelsea, Mich.
Pennybacker, J. E., Washington, D. C.
Peerless Brick Machine Co., Minneapolis, Minn.
Peerless Portland Cement Co., Union City, Mich.

Rackel, H. E., Cleveland, Ohio.
Rackel, E. E., Cleveland, Ohio.
Reeves, W. T., New York, N. Y.
Reiland, A. F., Hoboken, N. J.

Scott, H. M., Allentown, Pa.
Skinner, T. H., Kenwood, N. Y.
Smith, B. S., Chicago, Ill.
Swennson, A. S., Silvis, Ill.
Stubbs, R. C., Dallas, Texas.
Steel, G. D., Philadelphia, Pa.
Stade, A. A., Chicago, Ill.
Strehan, G. E., Chicago, Ill.
Schmidt, G. F., St. Mary's, Ohio.
Slater, Willis A., Urbana, Ill.
Sandusky Portland Cement Co., Sandusky, Ohio.

Thompson, S. E., Newton Highlands, Mass.
Taylor, H. A., Jackson, Mich.
Taylor Co., Ronald, New York, N. Y.
Talbot, K. N., Pittsburgh, Pa.
Tubesing, W. F., Milwaukee, Wis.
Trussed Concrete Steel Co., Detroit, Mich.

Ubbink, Joe, Port Washington, Wis.
Ulrickson, C. E., Jackson, Mich.
Universal Portland Cement Co., Chicago, Ill.

Van Doorn, J. C., Minneapolis, Minn.

Wight, F. C., New York, N. Y.
Whited, Willis, Harrisburg, Pa.
Wig, R. J., Washington, D. C.
Ward, H. H., New York, N. Y.
Whipperman, Frank, Omaha, Neb.
Williams, Warren, Coon Rapids, Iowa.
Wilson, P. H., Philadelphia, Pa.
Wright, D. I., Ironton, Ohio.
Walters, G. C., Atlanta, Ga.
Wetzstein, M., Cincinnati, Ohio.
Williamson, F. L., Kansas City, Mo.
Whipple, Harvey, Detroit, Mich.
Wright, C. O., Chicago, Ill.
Wilson, E. B., Chicago, Ill.
Wabash Portland Cement Co., Detroit, Mich.
Woodyard, J. F., San Antonio, Tex.

Young, R. W., Paullina, Iowa.

Zeidler, J. L., St. Joseph, Mo.

AMERICAN CONCRETE INSTITUTE

PROCEEDINGS
OF THE
TENTH CONVENTION.

This Association is not responsible, as a body, for the statements and opinions advanced in its publications.

THE USE OF CONCRETE IN HYDRAULIC WORKS.

ANNUAL ADDRESS BY THE PRESIDENT,
RICHARD L. HUMPHREY.*

The speaker has received during the past year a number of requests from various parts of the country for information relative to the durability of concrete in both fresh and sea water. It would seem desirable, therefore, to discuss in this address the use of concrete in hydraulic works, with special reference to its durability. The speaker's first experience in the use of concrete in hydraulic works was in the construction of the concrete bulkhead along the Delaware River, Philadelphia, Pa., in the early nineties. It has been his good fortune to inspect the important structures of concrete not only in this country but in Europe and also those testing laboratories in which special investigations are being conducted as to the effect of sea water upon concrete. This information has been further supplemented by the experience gained in the investigations conducted at Atlantic City, N. J., while the speaker was in charge of the investigations of structural materials for the United States Government.

The construction of canals and waterways extends back several thousand years before the Christian era, although the use of cement in such structures began with the introduction of the

* Consulting Engineer, Philadelphia, Pa.

canal lock. Notable examples of the early use of cement are the Roman aqueducts, a number of which are still used in supplying water to the City of Rome.

The material used in the construction of these ancient structures was little better than hydraulic lime; that used in the Roman structures was a mechanical mixture of the volcanic ash or tufa from Pozzuoli near Rome, and slaked lime, corresponding to the slag cement manufactured in this country from granulated basic blast furnace slag and slaked lime. These structures in which this particular binding material was used were for the most part of masonry. The production of Portland cement came about through the search for a suitable material which would harden under water, for use in rebuilding the Eddystone lighthouse off the English coast. In the earlier works, concrete was used in large masses, the binding material was a hydraulic lime and later a natural hydraulic cement. The development of our modern waterways with an increasing demand for economy in connection therewith has led to an almost exclusive use of concrete and reinforced concrete for locks, dams and other structures.

This progress has been so rapid that today the almost indispensable qualities of this plastic material, which lends itself with economy to all forms of construction, has resulted in works which otherwise would have been impossible. In many parts of the country where stone and other building materials are not available, the materials for concrete are usually available. This is particularly the case in the reclamation of arid land by the United States Government where many structures have been possible because of the availability of concrete materials through whose use there has resulted not only economy in construction but also great reduction in cost of maintenance on account of its permanency and durability.

A large proportion of the enormous annual production of Portland cement is used in hydraulic works. This application of cement can be best discussed by illustrating the principal structures both in fresh and sea water and pointing out for each the advantages of concrete.

The early uses of concrete in this country in hydraulic works was in connection with the construction of canals, where it was used in the masonry walls of the locks and other similar work.

Natural cements were used for this purpose and a number of natural cement plants were established in various parts of the country, the purpose being to supply the cement needed in the construction of these canals; the first cement was produced in connection with the Erie Canal in 1818. The Potomac Canal, now the Chesapeake and Ohio Canal, is one of the earlier canals and in its history George Washington's name is very much interwoven in various capacities in connection with its construction and management. Following this first application of concrete it was used in harbor work. Some of the earlier attempts show a rather amazing conservatism in the crude application. In all of these structures concrete was used in mass and it is only in the last few years that the much more economical and efficient use of reinforced concrete has been attempted. At the present time there seems to be no limit to the application of concrete in all sorts of structures for hydraulic works, not only in fresh but in sea water.

In this application of concrete, the United States engineer officers have been pioneers, since the improvements of the rivers and harbors of this country by the Government are under their direction.

So many canals have been built in this country in which concrete has been used in the construction of the locks and dams that it would be impossible within the limits of this address to describe in detail each application. Only the most notable of these canals will be referred to, the first being one of International character, viz. the Panama Canal, in which upwards of five million cubic yards of concrete have been used in the construction of its locks and dams. Even assuming that there was sufficient suitable material available for the construction of these works of masonry, the time required for the completion of the canal and the cost of its construction would have been enormously increased had it been necessary to use stone masonry instead of concrete. The saving of millions of dollars in actual construction is probably not so important as the speed with which the canal was completed through the use of concrete. The various applications of concrete in the construction of this canal were fully described in a paper by S. B. Williamson.*

* See *Proceedings*, Vol. VIII, p. 326.

The illustration given (Fig. 1) is a view of the Pedro Miguel Locks during construction and illustrates the magnitude of these great locks and the various methods of construction, but is also illustrative of the magnitude of all the work along this canal. The collapsible steel centers used in construction of the conduits,—the wood forms for constructing the lock walls and the mechanical devices for handling the concrete, may all be seen in this view. The handling of concrete on the Panama Canal, involving such enormous quantities, reached a greater development than has been attained in any other work in this country. The mixers were not only very large but the quantity of the material handled each day was so extraordinarily large that the economical management of the plant was of prime importance. In connection with

FIG. 1.—PEDRO MIGUEL LOCKS, LOOKING NORTH FROM EAST BANK.

the Gatun Locks an automatic railway carried the material from the storage bins to the mixers, from which the concrete was discharged into buckets which were conveyed by train to a point where cranes or overhead cables could move the bucket to the point where the concrete was being placed.

Next in importance to the Panama Canal is the New York State Barge Canal, which, although not as long or as wide as the Panama Canal, is of much greater extent and requires, therefore, a much larger quantity of material in its construction. It is perhaps not given the prominence it deserves because it is constructed under the auspices of a state and not of the United States and so is not of International importance.

Portland cement concrete is being largely if not entirely used in its construction. The various works of this canal are of the character which will be illustrated in connection with other works and they will not, therefore, be described in detail. The use of concrete in this canal was described by Russell S. Greenman.* The extensive use of concrete in the head gates, dams, and other structures has shown that without this material the cost would have been greatly increased and the speed materially decreased.

In the operation of the canal the most important portions of the structure are the locks. In the earlier canals of this country

FIG. 2.—CONCRETE SHIP LOCK AT BLACK ROCK HARBOR, NEW YORK.

the walls of these locks were of masonry laid in natural cement mortar and later laid in Portland cement mortar. Now these locks are built entirely of concrete, thereby increasing the facility and speed with which they may be constructed and largely decreasing the cost. Perhaps one of the most interesting locks is that shown in Fig. 2, built in connection with the ship canal in Black Rock Harbor near Buffalo. A coffer dam completely surrounds the locks, the massive walls of which were constructed of concrete, without interference with the river traffic.

* See *Proceedings*, Vol. VI, p. 196.

In the operation of canals it is necessary to erect dams and other controlling works to so regulate the flood waters of the river that the required depth in the canal may be maintained. Numerous controlling works of this nature are to be found throughout the country, the type of the construction being dependent upon local conditions; concrete lends itself admirably as a plastic material to the wide diversity of forms which these structures must have. As an illustration of the use of concrete in the construction of dams it is almost impossible to decide on the view to take. The Shoshone Dam, forming a part of the United States irrigation project in Wyoming, was built in an almost inaccessible

FIG. 3.—GRANITE REEF DAM, ARIZONA.

canyon, of concrete composed of the crushed granite obtained from the red granite walls between which the dam was constructed. The dam is one of the highest in the world and forms a lake extending for a distance of 12 miles back from its crest. Many of the dams of the New York State Barge Canal and the Panama Canal are much larger, but not one is so picturesque.

The Reclamation Service has many interesting structures which serve as monuments to the engineering skill of this branch of the United States Goverment. The value of concrete in the construction of these works cannot be overestimated. In many

parts of the territory covered by this work the inaccessibility and lack of the materials of construction other than sand, crushed stone or gravel has made concrete the only available material. Fig. 3 is a view of the Granite Reef Dam, Arizona, one of the many controlling dams for impounding the water used for irrigation purposes.

One of the important features of irrigation work is the dis-

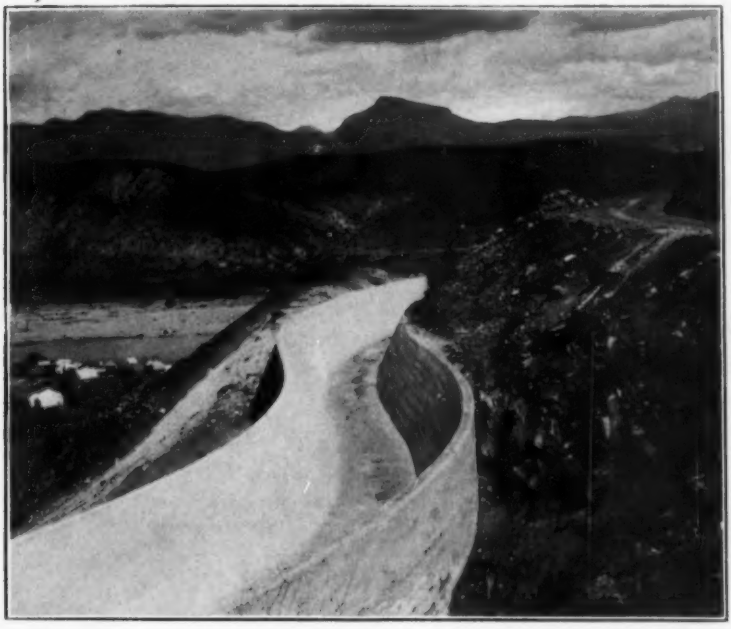

FIG. 4.—A PORTION OF THE CONCRETE-LINED POWER CANAL NEAR ROOSEVELT, ARIZONA.

tribution of the water from the impounding reservoirs through the various main and branch canals to the land to be irrigated. It is essential that little of this water shall be lost in transit and a study has been made of the losses which result from leakage, evaporation and other causes. It is, therefore, frequently necessary to line the canals with concrete in order to prevent ground leakage, while in some projects the water is carried in covered conduits to prevent the great loss by evaporation in this arid land.

Fig. 4 shows a portion of the concrete-lined power canal near Roosevelt, Arizona. It will be noted that part of this lining outside the cut becomes a retaining wall.

It is frequently necessary to carry the canal over a ravine, in which case concrete is an admirable material for the construction of these viaducts, not only as to economy in the cost of structure but also as to its water-tightness, which is illustrated by the view of aqueduct 8 on the line of the Illinois and Mississippi Canal (Fig. 5).

The Reclamation Service has a number of plants for the manu-

FIG. 5.—AQUEDUCT NO. 8 AND LOCK NO. 27, ILLINOIS AND MISSISSIPPI CANAL.

facture of reinforced concrete pressure pipe used in the distribution of water; this pipe can be manufactured and placed for very much less money than cast iron pipe, and there is a saving not only in the cost of manufacture but of the cost of transportation of cast iron pipe. Another type of pressure pipe is illustrated by the reinforced concrete conduit 5 ft. $3\frac{1}{2}$ in. in diameter on Simm's Creek, Sun River Project, Wyoming, which was built continuously in place.

A striking example of the adaptability of concrete to unusual forms of construction is illustrated by the view (Fig. 6) of the main Tieton Canal in the Tieton Canyon, Yakima Project, Wash-

ington. The rapid fall of the Tieton River is such that it is impossible to place a concrete lining in the canal and it became necessary, therefore, to form the sections of the canal, and after they had properly hardened they were transported and placed in position as shown.

In connection with water power development concrete again proves itself to be a material of unequalled value. The construction of the main shafts and conduits and other works connected with water power development can all be advantageously

FIG. 6.—MAIN TIETON CANAL, YAKIMA PROJECT, WASHINGTON.

constructed with concrete and almost always at a considerable saving in the cost. The view (Fig. 7) is the main conduit of reinforced concrete of the Canadian Niagara Power Company.

The earliest use of concrete was in harbor improvements in which it was used in construction of quay walls, piers, docks, and other structures. The speaker was connected with the initial construction of the bulkhead (Fig. 8) along Delaware Avenue in the City of Philadelphia in 1897, in which the saving in the cost and the permanency of the structure proved concrete to be

one of the most economical materials. This wall was constructed by placing 90-ton blocks of concrete on a mattress filled with mortar resting on the top of piles and casting the walls of concrete in place above the high water line, as shown in the illustration. This wall is over 16 years old and has proved satisfactory in every way.

Another purpose for which concrete has proved to be indispensable is in the construction of breakwaters, of which there are many types. The method of construction varies with the location. Some are constructed by placing the concrete in forms;

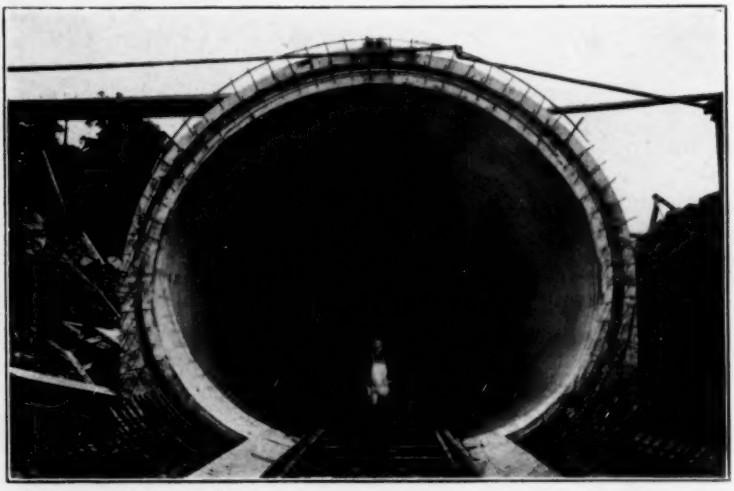

FIG. 7.—REINFORCED CONCRETE CONDUIT, CANADIAN NIAGARA POWER COMPANY.

in others it is composed of large blocks of concrete, molded on land and allowed to harden before being so placed as to form a solid mass; while in others, smaller blocks are so placed as to form pockets which are filled with gravel, stone or other similar material, the whole extending above high water line and upon which is cast a solid coping of concrete; and still another type (Fig. 9), proposed by Major Judson of the Corps of Engineers, U. S. A., consists of building on land caissons of reinforced concrete, which are allowed to harden and are then launched and floated over their final resting place and sunk by filling with water, sand, gravel or

broken stone. Generally a lean concrete is placed about 4 feet thick as a base for the coping.

The use of reinforced concrete caissons for breakwaters and bulkheads is rapidly growing and is extending to various parts of the world. These caissons prove of great value in the construction of lighthouses where the exposure to wave action is such as to render the erection of any structure difficult. The caissons can be floated to the desired locality and sunk into position; they possess decided advantages as to economy in construction,

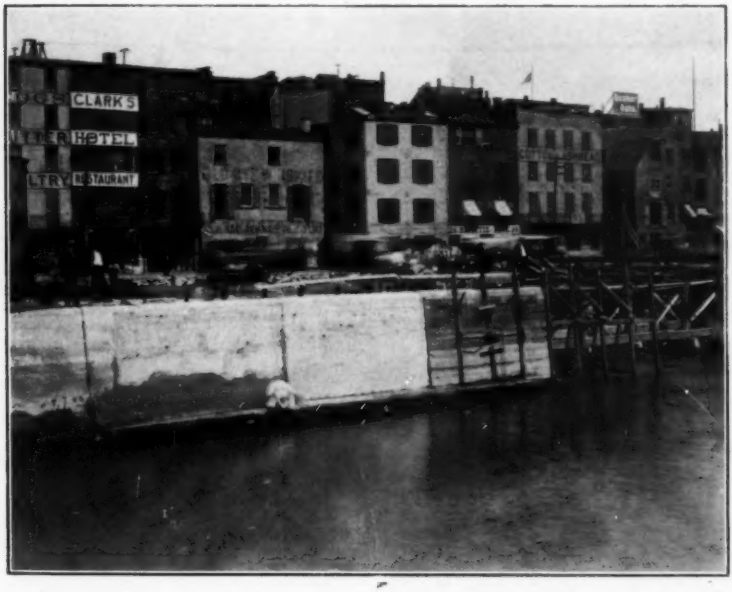

FIG. 8.—CONCRETE BULKHEAD ALONG DELAWARE AVENUE, PHILADELPHIA, PA.

and durability; and their stiffness and substantial character make them practicable for towing for considerable distance regardless of the condition of the sea. In view of the rising cost of timber and its short life under conditions of exposure to sea water, it is evident that this type of construction will be increasingly used in the future.

Fig. 10 is a breakwater consisting of molded blocks forming compartments which have been filled with gravel upon which a solid concrete coping has been placed.

In the protection of shores from the scour either of the sea or of the river, concrete again proves invaluable. One of the most notable uses of concrete in connection with sea exposures is the Galveston sea wall which was erected immediately following the disastrous flood which destroyed the greater part of this unfortunate city. Through the construction of the Breakwater at Galveston the city was protected against damage from future floods; the toe of the wall is protected by granite blocks and the top

FIG. 9.—FILLING REINFORCED CONCRETE CAISSON WITH LEAN CONCRETE, ALGOMA HARBOR, WISCONSIN.

raises the level of the city several feet above high tide and has proved to be a magnificent barrier against the sea.

Another barrier to prevent erosion of earth embankments is that constructed along the Little Miami Bottoms in the vicinity of Cincinnati, Ohio. This reinforced concrete slab covers and protects the mud embankment of Beechmont Avenue across the Little Miami Bottoms from the scour of the floods in the Miami River. It is about one mile long, 10 to 15 ft. high and 5 in. thick.

Fig. 11 is another interesting structure devised by Major Shultz of the United States Engineer Corps. It is a reinforced concrete dike constructed at St. Joseph, Mo. These dikes are usually built of timber, but their lack of stability and durability has led to their construction of reinforced concrete, for the reason that this type of dike is more substantial and durable, the cost of repairs is reduced to a minimum and in many cases its first cost is less than that of timber.

In the construction of piers and wharves, concrete again proves to be the most suitable material. These structures for

FIG. 10.—BREAKWATER AT BUFFALO, N. Y., SHOWING MANNER OF CONSTRUCTION.

the most part are built on wooden piles and because of the short life of the piles have proved expensive not only as to first cost but as to maintenance; this is particularly true on the Pacific coast where the life of the piles is extremely short because of the destructive limnoria and teredo. The reinforced concrete pile has, therefore, come into increasing favor as a substitute for wooden piles. In many cases economies can be effected by reason of the fact that fewer piles can be used and the concrete slab can be placed directly on the tops of the piles at a considerable saving in the cost. The advantage of this pile as to permanence and cost of maintenance cannot be overestimated. These structures of

concrete are generally found to be less costly than timber construction besides having the additional saving in the decreased cost of maintenance. A great variety of piles are manufactured. Some are molded on land and when sufficiently hardened are driven or jettied into position; others are formed by driving a metal cylinder or shell where the pile is required which is then filled with concrete, and still others are made by driving a metal cylinder or shell which is withdrawn and the hole left in the ground filled with concrete as the shell is withdrawn. Again, hollow cylinders

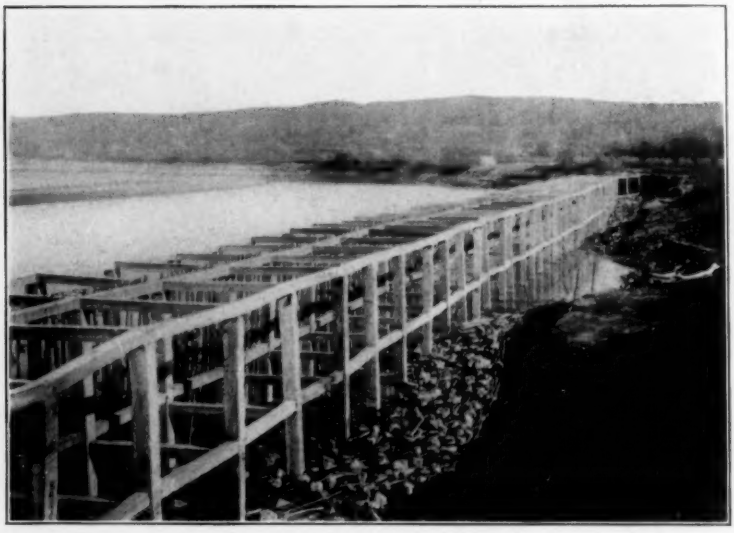

FIG. 11.—REINFORCED CONCRETE DIKE AT ST. JOSEPH, MISSOURI.

of reinforced concrete are molded and when properly hardened are placed in position, the water pumped out and the interior filled with concrete.

Fig. 12 shows the support for pier No. 8 built by the Bureau of Yards and Docks at the Navy Yard at Puget Sound, Washington. The method of construction consists in building hollow cylinders of reinforced concrete having an enlarged base, which are placed in position and filled with gravel, stone or concrete and upon which the structural supports of the pier of reinforced concrete are constructed. The view shows these cylinders in

position with the projecting reinforcement around which the reinforced concrete beams and girders of the deck of the pier are cast.

Similar wooden hollow cylinders were used in the construction of the wharf at Fort Mason, San Francisco, California. In this case the wooden cylinder was placed in position, filled with concrete and the shell was removed after the concrete had properly hardened. Upon these concrete pillars the superstructure of reinforced concrete was placed.

FIG. 12.—REINFORCED CONCRETE PILE SHELLS FOR PIER 8, NAVY YARD, PUGET SOUND, WASHINGTON.

Another use of concrete for timber work exposed to sea water, is to encase the pile or timber with a jacket of reinforced concrete and thus protect it against the limnoria, teredo or rot.

Fig. 13 is a view of the reinforced concrete sheathing used in the harbor improvements at Baltimore, Md. This sheathing was cast on land and after it was properly hardened was driven and formed a tight bulkhead because of the tongues and grooves in the sheathing. A feature about reinforced concrete piles is that they may be driven with very much heavier hammers than

are commonly used for wooden piles, and when properly cushioned they stand such driving without crushing or otherwise becoming defective. One notable instance of the severe treatment which these piles are likely to receive is the quay wall which rests on a coral reef, built by the Hennebique Construction Company, at the Navy Yard, Key West, Florida. The frequent occurrence of an intermediate crust of coral rock made it necessary to puncture this in order that the pile might have a solid bearing on the coral reef. This crust was frequently mistaken for the coral reef and

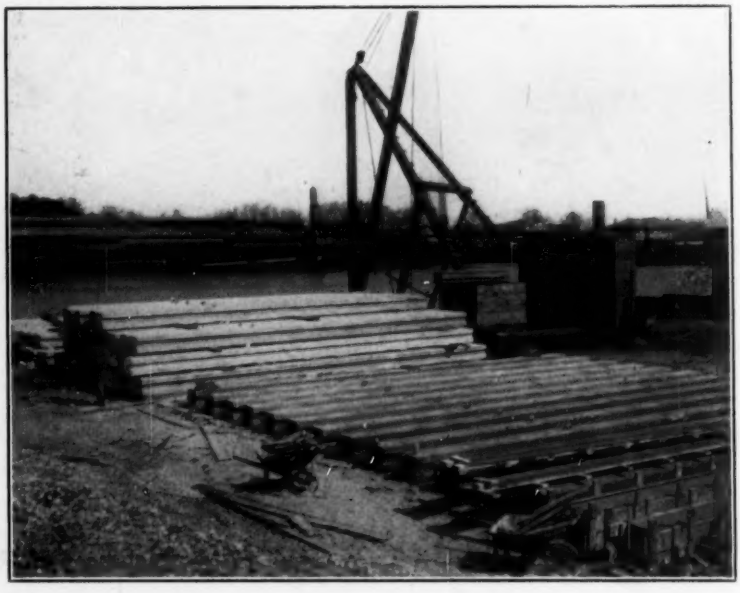

FIG. 13.—MOLDING YARD FOR REINFORCED CONCRETE SHEET PILING, BALTIMORE, MARYLAND.

in trying to drive through this the pile was broken. These piles were provided with hoops at the butt and a cast iron shoe at the point.

The proved economy in the cost and the durability have fully demonstrated the value of the reinforced concrete pile and it is gradually supplanting the wooden pile.

Reinforced concrete piles can be built to almost any length,

certainly to lengths upwards of 60 ft. and in these lengths they are much more economical than wooden piles.

Another interesting use of concrete is in the construction of drydocks of which there are a number in this country. The constructors, however, seem to think it necessary to go to the additional expense of either facing the entire drydock with stone (usually granite), or at least facing the walls at the entrance and at the water line. This is an unnecessary expense as concrete

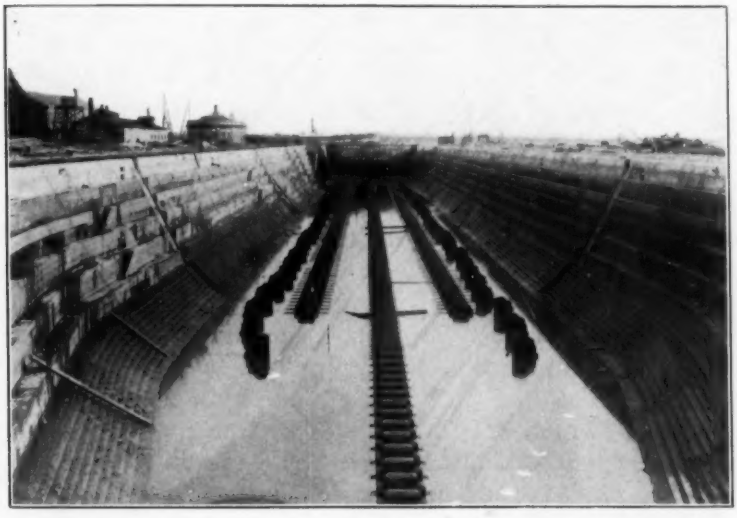

FIG. 14.—CONCRETE DRY DOCK, LEAGUE ISLAND NAVY YARD, PHILADELPHIA, PENNSYLVANIA.

can be used for the construction of the entire drydock at a great saving in cost over stone and with a minimum cost for maintenance. The dry dock at the League Island Navy Yard, Philadelphia, Pa. (Fig. 14), is constructed entirely of concrete.

By reason of the great difficulty of constructing lighthouses which must necessarily be at greatly exposed places, concrete has proved again to be invaluable. Many of the lighthouses built by the United States Lighthouse Board are entirely of concrete. Some consist of heavy cast iron cylinders filled with concrete. A growing practice, however, seems to be to construct a base with a pneumatic caisson of wood and build a central pier, of 20 or more feet in

diameter, upon which the lighthouse is built; or to form this base in a caisson similar to that described in Fig. 11. Such caissons can be built on shore and can be towed to the site, loaded with broken stone or gravel until they settle into the desired position; on this caisson as a base the lighthouse is built. This is also true in the construction of breakwaters.

Concrete, to properly withstand the action of sea water, should be allowed to harden before it is subjectd to the sea water. Where the structure is constructed in the open sea, this is almost impossible and it is, therefore, necessary to protect it against the sea. The difficulty of constructing concrete work in the sea, where it is subjected to tides and storms under conditions by which it is completely submerged, is easily understood and it would seem desirable that such structures should be built, whenever possible, of blocks of concrete molded on land and allowed to properly harden before being placed in position.

A great deal has been said concerning the disintegration of concrete in water, especially sea water. In fresh water the disintegration is the result of frost action and takes place between the tides. This is likely to occur where the concrete is porous and is lacking in density. With concrete properly mixed and hardened, and of the requisite density, there is little or no damage from frost. In sea water this is equally true. It was formerly the general practice throughout the world to mix concrete quite dry, *i. e.* so that the water would just flush to the surface under continued tamping. Permeable structures resulted, which permitted the surrounding water to penetrate to the interior of the mass, especially in that portion between the tides, where there was danger of disintegration from frost action.

The speaker has inspected structures of concrete in various parts of the world, has visited the principal laboratories in which studies are being made of the effect of sea water or alkalies on concrete, and has also been identified with the United States Government Experiments carried on under his direction at the United States Geological Survey laboratory at Atlantic City, N. J. It is his opinion that it is perfectly practicable to build structures of concrete or reinforced concrete both in fresh and alkaline water that will not be damaged in any way by the action of frost, sea water or other alkalies.

The view (Fig. 15) of Pier No. 1 of the United States Navy Yard at Boston, Mass., shows clearly the effect of properly and improperly mixed and placed concrete. Rear-Admiral Richard C. Hollyday was in charge of the Boston Yard at the time this pier was constructed in 1901–1902 and he informed the speaker that the two portions were by different contractors. The outer end was built by Miller and Ellis in 1901, and the shore end by Norcross Brothers in 1902, the same material having been used in both portions. The concrete in Norcross Brothers' end was mixed fairly wet, while that built by Miller and Ellis was dry

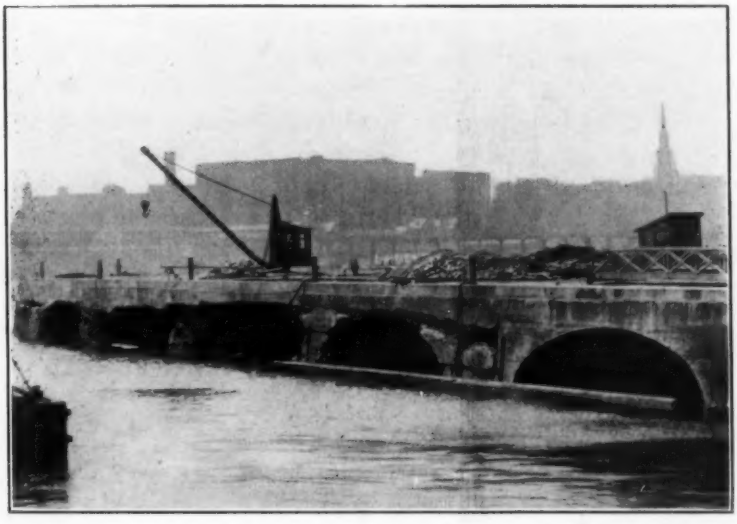

FIG. 15.—PIER NO. 1, NAVY YARD, BOSTON, MASSACHUSETTS.

concrete of a leaner mix. The resistance between tides of the two concretes is evident, that on the right side of the picture being unaffected while the other is badly disintegrated; the submerged portions of both were practically undamaged. The lesson taught by this experience is that well proportioned, dense concrete will withstand the action of sea water where lean, dry mixed concrete will fail. Inasmuch as many of the earlier structures were built of dry mixtures, the resulting permeable concrete has shown the effect of frost between tides. The speaker has found in his investigations that almost universally the disintegration of concrete takes

place between high and low water, and has never found an instance of the disintegration of submerged properly proportioned dense concrete. It has also been his experience in the tropical waters where there is no frost action, that concrete of reasonable density is unaffected. After disintegration of the concrete has started through frost action, there is undoubtedly some chemical action of the sea water on the concrete. The speaker has never found an authenticated instance where concrete had disintegrated from the chemical action unless it had been permeated by sea water before it had set.

In the states of Wyoming, Montana, and the Dakotas, what is known as the Black Alkali District, where the soil is impregnated with this alkali, disintegration of concrete has occurred at the ground water line. The ground water is drawn up by capillary action and the rapid evaporation of this water and consequent rapid crystallization in the pores of the mass destroys the bond, and results in complete disintegration. Under these conditions, stone and brick and other building materials are similarly affected. This is notably so in the vicinity of Great Falls, Montana, where stone buildings, brick sewers and similar masonry structures are largely destroyed by this action.

An important matter in the erection of reinforced concrete buildings in salt air is the proper protection of the reinforcement for the reason that the corrosion of the improperly imbedded metal may result in serious damage to the structure. At Atlantic City, N. J., one of the large piers has been seriously damaged because of the use of a porous aggregate which permitted moisture and air to reach the reinforcement and the corrosion of this has stripped the concrete from it. The aggregates, therefore, under such conditions should be hard and dense and so proportioned as to secure a concrete of maximum density.

In conclusion, it would seem evident from the examples cited that concrete lends itself to a great variety of structures in both fresh and sea water and has proved to be one of the most economical and durable materials. It is, of course, necessary to observe the necessary precautions pertaining to the use of concrete, more so in sea water than in fresh water; there is no question that there are numerous structures that have successfully resisted the action of sea water. On this point attention is called to the interesting sea water

experiments conducted by French engineers at Cristobal, Panama, in 1886. These tests consisted in exposing large cubes of concrete, of various proportions and compositions, to the action of sea water. The blocks were placed on the shores of the Atlantic Ocean at Cristobal where they have been since tossed by the waves for nearly thirty years. While their edges have been slightly rounded, these blocks of concrete are still perfectly hard and show no evidence of softening or disintegrating.

Some interesting experiments are being conducted by the Aberthaw Construction Company in the Boston Navy Yard; long prisms of concrete composed of various materials and mixed in varying proportions have been exposed for a number of years to the action of sea water and the results thus far indicate that when it is properly mixed and placed concrete is unaffected by sea water.

Its great durability, increasing in hardness with age, and its freedom from necessity of repair, makes concrete one of the most valuable of the materials of construction from the point of economy as regards the cost and the maintenance of the structure in which it is used. The speaker's visits to the various laboratories of Europe and the results of the tests conducted by himself and others, lead him to the opinion that where concrete is properly proportioned, mixed and placed so that the resulting mass is of maximum density, it affords ample resistance to the action of both fresh and sea water, especially if sufficient time is given the concrete to harden before its subjection to this action; and he is further of the opinion that good practice demands that concrete shall be mixed a sufficient length of time, without too much water, so that there results a mass of viscous consistency which will flow readily and in which the ingredients will not separate. Increased mixing of concrete develops colloids and results in a sticky, viscous, dense, impervious mass, which will shed water and produce a concrete of maximum strength and resistance to the action of both fresh and sea water.

The increasing use of concrete both with and without reinforcement and the testimony of the many excellent structures already in existence lead to the conclusion that because of the intrinsic merits of this material it is the most suited and the best adapted of the materials of construction for use in hydraulic works.

SPECIFICATIONS FOR DRAIN TILE.

By A. Marston.*

Need of Standard Specifications for Drain Tile.—At present there are no standard specifications for drain tile, although great numbers of tile drains are constructed every year in the United States alone; and although the value of each of these tile drains is absolutely dependent upon the stability and durability of the drain tile of which it is made, engineers do not possess the information on which to base reasonable specifications which will secure good work without unnecessary cost. Even within the limits of a single state, as in Iowa, it has been customary up to the present time for each drainage engineer to follow his own individual notions in his specifications, and to use quite vague language concerning the qualities of the drain tile required. In carrying on the work the acceptance or rejection of the drain tile supplied by the manufacturer has depended, to a very large degree, upon the whims, or rather notions, of the individual drainage engineer. One would reject a large percentage where another would accept practically all, of the same quality of tile.

Worse than this, there has been a large amount of failure of large drain tile owing to lack of strength to support the weight of the ditch-filling material. In recent years the use of very large drain tile has increased enormously. Drainage operations are being carried out on a very large scale, and farmers object more and more strenuously to having their fields injured by the open drainage ditch. Tile drains of 36 in. in diameter are now common, and those of 48 in. not unknown. It is with tile of 20 in. diameter and upwards that most of the trouble with cracking has occurred. Until now engineers have had no definite scientific data on which to base standard specifications which would prevent this cracking, without unreasonable cost which would prevent the use of the drain tile instead of the open ditch.

Committee C-6, American Society for Testing Materials.—Under these circumstances the American Society for Testing

* Director, Iowa Engineering Experiment Station, Ames, Iowa.

Materials, which is the recognized authority in the United States for the preparation of standard specifications for all kinds of materials of construction, has appointed a Committee to undertake the preparation of standard specifications for drain tile. This Committee has been in existence three years. It found the problem assigned to it one of extreme difficulty and delicacy. It has been fortunate in enlisting the services of a number of experimental laboratories of high reputation and in securing the co-operation of widely known manufacturers and engineers. It has just completed a series of 600 strength tests made especially for its use, and has under way an extensive series of absorption tests, likewise made especially for its use. It is now hoped that in the immediate future the Committee can formulate fair, reasonable and safe standard specifications for drain tile.

Nature of the Problem of Preparing Standard Specifications for Drain Tile.—Committee C-6 has found the problem of preparing standard specifications for drain tile to be complicated and delicate.

First. Drain tile of quality used extensively, and with satisfaction in many cases, are made of many different materials. In the case of clay drain tile, one class of manufacturers has used surface clays producing a very porous tile wall which, nevertheless, have proven durable in thousands of miles of farm drains, especially in the smaller sizes; another class of manufacturers has used impure fire-clays, making very strong tile, but with porosity somewhat higher than in the case of shale tile; a third class of manufacturers has used shale, which, when thoroughly vitrified, makes in general a tile not only strong but with a very low degree of porosity. All of these clay tile have proven satisfactory in extensive use for many conditions and purposes. Further, cement tile have come into extensive use, and have been made in almost all imaginable proportions, varieties of cement, kinds of aggregate, and processes of manufacture and curing.

Second. The methods of laying drain tile in the actual construction of tile drains vary greatly. Most commonly they are laid in such a manner that the bottom bearing extends over only a portion of the lower one-half of the external surface of the tile; and also in such a manner that the tile receive little or no side support from firmly packed earth. In some cases, however, drain

tile have been laid as carefully as is required in standard specifications for sewer pipe construction, which generally require very careful bedding of the pipe and tamping of the earth at the side. In a few cases drain tile have been laid, under unusual conditions, in cradles of concrete.

Fair and reasonable standard specifications for drain tile will take into account all these different materials and methods of laying.

Requirements which should be incorporated in Standard Specifications for Drain Tile.—The requirements which should certainly be incorporated in standard specifications for drain tile may be grouped under three heads:

1. General Requirements.
2. Absorption Requirement.
3. Strength Requirements.

It is possible that additional requirements may need to be added, such as special tests of durability, freezing and thawing, and resistance to acids and alkalis. Taking up only the three requirements mentioned above, they may be discussed as follows:

1. *General Requirements for Drain Tile.*—These will include such specifications as are now very commonly made to the effect that the tile shall be good, sound tile; free from cracks, and fire checks; with uniform strong, dense structures; giving a clear ring; regular and true in shape; etc., etc. It is not necessary to discuss the general requirements in detail, for almost any group of good engineers should have little difficulty in arriving at comprehensive general requirements upon which all could agree. General requirements will include, also, provision for field inspection of drain tile.

2. *Absorption Requirements.*—The percentage of absorption of drain tile is not in itself a cardinal quality of the tile. It is now agreed by all competent drainage engineers that the proper place for the water to enter the tile is through the joints, and not through the pores of the tile walls. The absorption is specified as an indirect method of specifying the quality of the material in the tile walls. This being the case, it must be manifest that the percentage of absorption that it would be proper to specify for one kind of clay would not be the proper percentage to specify for all kinds of clay, nor necessarily for cement tile. Since the

percent of absorption is specified to secure a certain quality of tile wall, it would be really just as absurd to specify necessarily the same percent of absorption for surface clay as for vitrified shale as to specify that cement tile should be vitrified as well as shale tile. The proper per cent of absorption to require can only be determined as the result of extensive tests of tile which have been demonstrated by actual experiments to be good, indifferent or poor. Professor H. O. Withey, of the University of Wisconsin, is now making such a set of tests for Committee C-6.

3. *Strength Requirements.*—The strength of drain tile to carry the loads imposed by ditch filling, on the other hand, is a cardinal quality of the material. Unless the tile have a safe strength they are liable to be cracked in the ditch by the weight of the ditch filling. Since the weight of the ditch filling resting upon the tile is independent of the material of which the tile are made, the same strength should be specified for one kind of clay tile as another and the same strength for cement tile as for clay tile. The really difficult question to decide in connection with strength requirements for standard specifications for drain tile is what actual loads the tile are reasonably certain to be liable to have to carry for different depths and widths of ditches and varieties of soil; and the safety factor of strength which should be specified to provide for variations in the strength of the tile and in their loadings from ditch filling.

Requirements for Bearing Strength in Standard Specifications for Drain Tile.—There have been a sufficiently great number of cases in the construction of large drain tile where cracking has resulted from insufficient strength to carry the weight of the ditch filling, to make it advisable to adopt in Standard Specifications requirements for bearing strength which shall certainly prevent such cracking. However, to construct drain tile with the increased strength necessary to insure safety in deep and wide ditches will call for material increase in their cost. The average tile drain is not of uniform depth throughout its length. Comparatively limited portions are usually much deeper than the greater part of the drain. In some cases it would add greatly to the cost of the drain to require pipe throughout its length capable of carrying safely the loads in the limited deep stretches.

The ideal manner of specifying bearing strength in Standard

Specifications for Drain Tile would be to require that it shall be equal to the loads liable to be carried multiplied by a reasonable factor of safety, just as is the engineering practice in designing bridges, the floors of buildings and in fact almost all engineering structures. In reality it is little more reasonable to specify that drain tile shall be of one standard strength for all ditches, regardless of the actual depths and widths and varieties of soil, than it would be to require that all bridges shall be designed with a uniform amount of steel per linear foot, regardless of the span. The ideal plan would call for drain tile of the strength required in the greater part of the ditch to carry the loads, and would provide for the use either of stronger tile or a method of strengthening the ordinary tile throughout the comparatively limited deep portions of the ditch.

There are difficulties, however, in attaining to this ideal. In the first place, engineers have not yet generally learned an authoritative method for determining what loads drain tile are reasonably certain to be liable to have to carry in ditches of different depths and widths and varieties of soil. In the second place, there has never been a study of a sufficient number of cases in which drain tile have remained sound in the ditch to determine what factors of safety should be specified to make reasonable provisions for contingencies. In the third place, no standard method of testing drain tile has yet been adopted for the entire country.

Committee C-6 is earnestly endeavoring to overcome the various difficulties which have been enumerated. Among the possibilities for a solution may be mentioned the following:

1. The adoption of standard loads for different depths and widths of ditches and varieties of soil which it is reasonably certain that drain tile are liable to have to carry.

2. The determination of a factor of safety which experience with sound tile in actual ditches has shown to provide reasonable safety against cracking.

3. The division of drain tile into classes A, B, C, D, etc., as has already been done with water pipe, and the specifying of the minimum bearing strength per linear foot for each class.

4. The specification of limits of depth and width of ditches for each main variety of soil where drain tile of each class may be used without special precaution in laying.

5. The specification of an additional allowance, possibly stated as a percentage, which shall be granted for care in laying equal to that given in the best sewer construction practice.

6. A specification permitting the use of drain tile in depths and widths exceeding the limits specified under No. 4 above on condition that the pipe be strengthened by laying in a cradle of concrete.

Out of the careful consideration of the data already accumulated and still to be obtained, and out of the results of a careful study of all the considerations and possibilities mentioned in this paper, Committee C-6 hopes to be able to prepare standard specifications for drain tile which will be accepted generally as reasonable and safe.

RESULTS OF TESTS ON PLAIN AND REINFORCED CONCRETE TILE.

By George P. Dieckmann.*

The tests herein covered were made on plain and reinforced concrete tile, and were the beginning of an exhaustive investigation to be carried out along this line. The results thus far obtained are of sufficient interest to warrant their presentation at this time.

These tests were made at the suggestion of Mr. P. H. Atwood and were carried out at the plant of the Armstrong Cement Tile Company. The testing of the tile was with the assistance of the Engineering Department of the Iowa State College, witnessed by Messrs. Marston, Stewart and Atwood, who are members of Committee-6 on Specifications of Drain Tile of the American Society for Testing Materials. There were also a number of engineers present when the tests were made.

Materials.

Cement.—The Portland cement was tested according to Standard Specifications, with the following results:

Fineness	100-mesh sieve, 95.2. 200 76.8
Setting	Initial, 3 hr. 20 min.
	Final, 6 hr. 20 min.
Soundness	Perfect.

Tensile Strength in lb. per sq. in:	Neat.	1:3
24 hrs	310	...
7 days	690	250
28 days	740	300
60 days	765	330

Chemical Analysis:	Per cent.
Silica	21.00
Alumina	7.36
Oxide iron	3.18
Lime	62.70
Magnesia	1.70
Sulphuric acid	.71

*Chief Chemist, Northwestern States Portland Cement Company, Mason City, Iowa.

Sand.—The sand was sharp, clean and had the following granular composition:

	Per cent.
Passed on 100-mesh sieve	3.5
" " 50 " "	11.5
" " 30 " "	25
" " 20 " "	20
" " 10 " "	23
Retained on 10-mesh sieve	17

Reinforcement.—The reinforcement consisted of double hoops of No. 7 wire, 0.0176 in. diameter.

CONSTRUCTION AND CURING OF TILE.

All the tile were 28 in. diameter with $\frac{1}{10}$ wall thickness.

The mixture employed consisted of one part Portland cement and three parts of sand. A semi-wet mixture was used; the materials mixed dry in the batch mixer and then wet in a continuous mixer. Care was taken to mix the mortar as uniformly as possible. The tile was made on a tile machine, power tamped and cured for 48 hours in steam and for the remainder of the time in air until tested, with the exception of 4-5-6, marked W-0, which were wet before breaking.

RESULTS.

All the tile was tested according to the Iowa Standard Method on the Ames tile machine.

From Table I it will be noted that there were 7 series of tile tests, each covering three tile. Numbers 1 to 6 are plain concrete tile, marked D-0 and W-0, and 7 to 21 are reinforced concrete tile.

The wire hoops were imbedded $\frac{1}{2}$ in. from outside and $\frac{1}{2}$ in. from inner wall.

In looking over the results, it will be noted that the weights and measurements of the tile are very uniform throughout. The results obtained can also be considered uniform.

The wet tile, No. 4-5-6, show a lower breaking strength than the tile, 1-2-3, tested dry.

The first checking of the tile under the load, results which will be found in the upper figures, will practically average 6050 lb. whether the tile be plain or reinforced.

TABLE I.—TESTS OF ARMSTRONG 28-INCH CEMENT TILE.

Date.	No.	Type.	Number of Double Hoops.	Internal Diameter—Inches.		Average Thickness—Inches.				Length—Inches.	Weight—Lb.	Breaking Loads—Lb.			Per Double Hoop.	Strength Added by Reinforcing—Per Cent.	Modulus of Rupture—Lb. per Sq. In.	Time of Loading—Min. Sec.	Variations from Straight Edge—Inches.	Absorbtion—Per Cent.	Remarks.
				Vertical.	Horizontal.	Top.	Bottom.	Left.	Right.			Applied.	Total.	Per Foot.							
1-14-14	1	D-0	0	27.8	28.1	....	....	....	....	....	....	....	....	....	....	....	....	....	T St	8.3	
				28.0	28.1	2.70	2.72	2.78	2.75	29.8	617	6390	6790	2730	....	....	480	3:00	B-1/16	8.2	
1-15-14	2	D-0	0	28.1	28.2	....	....	....	....	....	....	....	....	....	....	....	....	....	T St	7.2	
				28.2	27.9	2.72	2.75	2.75	2.85	29.8	618	5820	6220	2500	....	....	430	3:30	B-1/16	7.0	
1-15-14	3	D-0	0	28.5	28.2	....	....	....	....	....	....	....	....	....	....	....	....	....	T-1/16	8.9	
				28.5	28.1	2.75	2.75	2.82	2.78	30.0	640	7270	7670	3070	....	....	520	3:50	B-1/8	6.5	
Average.	..	....		....	....	....	....	....	....	....	....	....	....	2770	....	....	480	....	.....	7.4	
1-15-14	4	W-0	0	28.4	28.2	....	....	....	....	....	....	....	....	....	....	....	....	....	T St	9.0	
				28.2	28.1	2.60	2.65	2.82	2.75	29.9	645	4470	4870	1950	....	....	370	1:15	B-1/16	8.4	In steam room
1-15-14	5	W-0	0	28.2	28.0	....	....	....	....	....	....	....	....	....	....	....	....	....	T St	6.3	27 hrs.
				28.0	27.8	2.62	2.75	2.82	2.78	30.0	650	5150	5550	2220	....	....	410	2:05	B-1/16	7.2	
1-16-14	6	W-0	0	28.0	28.2	....	....	....	....	....	....	....	....	....	....	....	....	....	T-1/16	8.3	29 hrs.
				28.4	28.2	2.62	2.82	2.85	2.62	29.7	650	5310	5710	2300	....	....	430	2:00	B-1/8	7.3	52 hrs.
Average.	..	....	..	....	....	....	....	....	....	....	....	....	....	2160	....	....	400	....	.....	8.1	Just before testing.
1-14-14	7	R-2	2	27.9	27.2	....	....	....	....	....	....	6460	6860	2760	....	....	500	2:40	.....	6.8	
				28.2	28.2	2.65	2.82	2.82	2.75	29.9	630	....	....	....	....	....	....	....	.....	7.4	
1-15-14	8	R-2	2	28.4	28.1	....	....	....	....	....	....	5820	6220	2500	....	....	420	2:10	.....	7.4	
				28.0	28.1	2.78	2.78	2.78	2.85	29.9	640	....	....	....	....	....	....	....	.....	8.0	
1-15-14	9	R-2	2	28.4	27.8	....	....	....	....	....	....	6460	6860	2740	....	....	480	2:30	.....	8.2	
				28.1	27.8	2.72	2.72	2.78	2.78	30.0	628	5220	5620	2250	2810	....	....	....	.....	8.0	
Average	..	....	..	....	....	....	....	....	....	....	....	....	....	2670	....	....	470	....	.....	...	
														....	....	....	...	....	.....	7.6	

1-14-14	10	R-3	3	27.9	28.0	....	....	....	....	....	....	5480	5880	2360	....	....	400	2:00	.....	9.1	Wires sheared
				27.9	28.1	2.75	2.75	2.82	2.75	29.9	616	6430	6830	2740	2230	16.1	....	1:25	.....	7.4	out inside top.
1-15-14	11	R-3	3	28.0	28.0	....	....	....	....	....	....	5120	5520	2210	....	....	440	1:55	.....	9.4	
				28.2	28.3	2.53	2.78	2.72	2.75	29.9	618	6820	7220	2900	2410	30.8	....	2:30	.....	7.6	
1-15-14	12	R-3	3	28.3	28.0	....	....	....	....	....	....	5320	5720	3290	....	....	450	1:45	.....	9.1	Wire necked
				27.9	27.8	2.57	2.78	2.82	2.82	30.0	623	7520	7920	3170	2640	38.5	....	....	.....	8.7	down at ½ pts.
Average	..	....	..	....	....	....	....	....	....	....	....	....	....	2290	....	....	430	....	.....	....	2 ruptured.
														2940	2440	28.5	....	....	.....	8.6	
1-14-14	13	R-4	4	27.9	28.0	....	....	....	....	....	....	6530	6930	2790	....	....	540	2:35	.....	5.9	Wires sheared
				28.2	28.1	2.57	2.87	2.62	2.72	29.8	628	8800	9200	3710	2300	32.7	....	1:40	.....	4.6	out inside top.
1-15-14	14	R-4	4	27.9	28.1	....	....	....	....	....	....	5670	6070	2440	....	....	440	2:35	.....	8.3	
				27.9	27.9	2.68	2.78	2.87	2.78	29.8	623	9070	9470	3810	2370	56.0	....	3:50	.....	6.7	
1-15-14	15	R-4	4	27.8	27.9	....	....	....	....	....	....	6420	6820	2740	....	....	520	2:50	.....	7.3	
				28.0	28.2	2.60	2.85	2.68	2.85	29.9	631	9930	10330	4150	2580	51.5	....	....	.....	7.2	
Average	..	....	..	....	....	....	....	....	....	....	....	....	....	2660	....	....	500	....	.....	....	
														3890	2420	46.7	....	....	.....	6.7	
1-14-14	..	....	..	27.9	28.0	....	....	....	....	....	....	5790	6190	2490	....	....	450	2:25	....	7.0	1 wire
1-16-14	16	R-4	5	27.9	28.0	2.65	2.72	2.72	2.78	29.9	629	11370	11770	4730	2350	90.1	....	6:00	Straight	5.5	sheared out
			5	27.9	27.8	....	....	....	....	....	....	6370	6770	2730	....	....	450	2:50	....	7.2	inside bottom.
1-15-14	17	R-5		28.1	27.8	2.78	2.78	2.78	2.90	29.8	627	12100	12500	5030	2500	84.6	....	6:00	....	7.7	
1-15-14	..	....	..	27.9	28.0	....	....	....	....	....	....	5930	6330	2540	....	....	440	3:05	....	8.4	1 wire
1-16-14	18	R-5	5	28.0	28.0	2.72	2.75	2.78	2.82	29.9	630	11820	12220	4910	2440	93.0	....	....	.....	7.1	sheared out
Average	..	....	..	....	....	....	....	....	....	....	....	....	....	2590	....	....	450	....	.....	....	½ length
														4770	2430	89.2	....	....	.....	7.2	
1-14-14	..	....	..	28.0	27.9	....	....	....	....	....	....	5840	6240	2500	....	....	500	2:30	.....	7.3	Wires sheared
1-16-14	19	R-6	6	28.3	28.0	2.53	2.75	2.85	2.75	30.0	625	11870	12270	4910	2050	96.7	....	5:30	.....	6.0	out inside
				28.2	27.8	....	....	....	....	....	....	5900	6300	2570	....	....	480	2:15	.....	9.0	top-3 2
1-16-14	20	R-6	6	28.0	27.7	2.62	2.78	2.62	2.90	30.0	617	12520	12920	5170	2150	105.0	....	5:30	.....	5.6	
				28.1	28.2	....	....	....	....	....	....	6170	6570	2640	....	....	460	2:25	.....	5.4	1 Wire
1-16-14	21	R-6	6	28.0	28.1	2.72	2.72	2.72	2.85	29.9	632	12970	13370	5370	2230	103.5	....	....	.....	4.6	sheared out
Average	..	....	..	....	....	....	....	....	....	....	....	....	....	2570	....	....	480	....	.....	....	between ½ pts.
														5150	2140	101.7	....	....	.....	6.3	
Total Average, Tile Nos. 1 to 21														2530	2400	....	450	....	.....	....	
Age of each tile, 2 months														....	....	....	....	....	.....	7.4	

Remark: Serial No. 18 Carried Applied Load of 12.200 lb. on 1/15/16.

The type R-2 with two wire hoops collapsed with the exception of tile No. 9, plain concrete tile.

Type R-3 with 3 wire hoops showed an increase over the first checking of 28.4 per cent.

Type R-4 with 4 wire hoops showed an increase of 46.2 per cent.

Type R-5 with 5 wire hoops showed an increase of 88 per cent.

Type R-6 with 6 wire hoops showed an increase of 102 per cent.

The results show the advantages of reinforced tile against plain tile. More work will be carried on on different size tile and different ways of reinforcing.

INVESTIGATION OF THE DURABILITY OF CEMENT DRAIN TILE IN ALKALI SOILS.

(Manufacture and Installation)

By R. J. Wig* and G. M. Williams.†

IN COOPERATION WITH

S. H. McCrory,‡ E. C. Bebb§ and L. R. Ferguson.‖

I. Introduction.

The disintegration of concrete when exposed to the concentrated salts in irrigated districts of the western part of the United States has been a subject of discussion by engineers and users of cement for the past ten or fifteen years. There are many concrete structures in these districts which do not appear to be affected by the salts but there are some which were apparently made of good materials and were well fabricated which show indications of being attacked.

There are many engineers who believe that well fabricated concrete will not disintegrate when exposed to these alkali salts and that many cases of failure which have been reported have not been caused primarily by the alkali but resulted from the use of poor aggregate, improper methods of fabrication or other causes which resulted in a poor quality of concrete.

A laboratory investigation was started in 1908 by the Technologic Branch of the United States Geological Survey to determine the effect of alkali waters on cements and concretes. In 1910 this work was transferred, by act of Congress, with all Structural Materials Investigations, to the Bureau of Standards. The investigations were continued and the results were published in 1912 as

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Technologic Paper No. 12.* Briefly, these investigations showed that practically all cements are attacked by alkali waters upon exposure in the laboratory, and complete disintegration can be obtained under certain conditions. Similar investigations have been made by other laboratories with similar results.†

In the laboratory, disintegration can apparently be obtained in two ways. If the cement specimen is somewhat porous and it is constantly supplied with a salt solution which is permitted to crystallize in the pores, disintegration may result from the mechanical force exerted. If hydrated cement is brought into intimate

FIG. 1.—CONCRETE TURNOUT ON IRRIGATION CANAL IN ALKALI DISTRICT.

contact with certain sulphate or chloride solutions the uncarbonated lime of the cement is subject to comparatively rapid solution with a resulting decomposition of the cement. Laboratory tests, however, must always be interpreted with caution as conditions often differ somewhat from service and it is on this account that a field investigation was undertaken in which cement mortar and concrete mixtures of various qualities could be brought into intimate contact with alkali salts under natural conditions.

The Bureau of Standards has made a field survey of concrete structures exposed to alkali waters in several of the western states.

* Action of the Salts in Alkali Water and Sea Water on Cements.

† Montana State Agricultural College, Circular No. 8, 1910; Bulletin No. 81, 1910. Colorado Agricultural Experimental Station, Bulletin No. 132.

There is a tendency for the cement user to attribute to alkali all failures occurring in these districts if any alkali is visible in the surrounding soil. Therefore such failures as occur in the eastern part of the United States, due to poor materials or improper methods of fabrication, are often excused in the irrigated districts as failures due to alkali.

A description of several of the structures which were examined will serve to illustrate the conditions as they exist.

In Fig. 1 is shown a small concrete structure known as a "turnout" for irrigation water, which was built about 1907. One portion of this structure is completely disintegrated while another portion is sound. The sound portion is a beam on the lower side extending into the wing walls exposed to the earth at each end and located so that half of it is above the concentrated alkali water and half below. The composition of the salts was found to be as follows:

	Per cent.
Water soluble	65.33
Insoluble	31.19
Loss at 110 deg. C.	3.14

Analysis of water soluble portion:

	Per cent.
CaO	.04
MgO	.38
Na_2O	43.60
K_2O	.11
SO_3	53.58
CO_2	2.19
Cl	.77

The following method was used for determining the water soluble portion:

Five grams of the sample were heated to 110 deg. C. for eighteen hours or until constant weight was obtained. This gave "loss at 110 deg. C." This dried residue was digested with 50 cc. of water, filtered and washed until practically free from salts soluble in water. The "insoluble" was dried at 110 deg. C. and weighed. Aliquot parts of the solution were taken for determination of soluble salts.

The form marks were still visible on the beam when examined in 1912, and it did not appear to have been affected in the least by the alkali salts. The remainder of the structure is so completely disintegrated that it can be torn apart with the hands, and the pores are filled with salts. This canal has never been used for the purpose of distributing irrigation water, so that the structure is exposed to the concentrated seepage water which collects from the higher surrounding land, and which flows through the ditch.

FIG. 2.—CONCRETE GATE CULVERT ON IRRIGATION CANAL IN ALKALI DISTRICT.

The beam was molded and cured in the yard and set into place in the "turnout" several days later, at the time the turnout was cast. No records were available to show the composition or method of molding, but it was stated that probably the same materials and proportions were used in both parts of the structure. The primary cause of failure of the disintegrated portion may not be the alkali salts, although it would appear that alkali might be responsible. The excellent condition of the beam, however, would demonstrate that concrete can be made which will resist,

at least for a number of years, the action of concentrated alkali of the character found at this locality.

Fig. 2 shows the lower end of a small concrete gate culvert which is badly disintegrated. Alkali salts are visible on the surface of the soil surrounding the culvert at the lower end. The water carried by the culvert is fresh irrigation water. The walls of the culvert at the upper end appear sound and normal. An analysis of the disintegrated concrete taken from the walls at the lower end give the following results. Two analyses were made of the sample, (*a*) of the solid lumps, (*b*) of the soft or crumbly portion:

Insoluble.	(*a*)	(*b*)
Sand, etc.	79.26	65.80
Soluble.		
SiO_2	3.29	3.60
Fe_2O_3	1.20	.80
Al_2O_3	1.57	2.06
CaO	7.02	13.64
MgO	.60	.55
SO_3	.14	.25
Cl	trace	trace
CO_2	4.67	8.82
Water, etc., at 500 deg. C.	2.18	4.39

The foregoing analyses computed to a "sand and moisture free" basis gives:

Soluble.	(*a*)	(*b*)
SiO	17.80	12.12
Fe_2O_3	6.49	2.69
Al_2O_3	8.50	6.93
CaO	37.98	45.90
MgO	3.25	1.85
SO_3	.76	.84
CO_2	25.22	29.67

After calculating the amount of MgO and CaO necessary to satisfy the CO_2 and SO_3 there is left in (*a*) 9.8 per cent CaO and in (*b*) 10.1 per cent CaO.

These analyses show no abnormality which would account for the disintegration. The sodium and potassium were not determined but they were evidently not in excess of one per cent. The SO_3, Cl, and MgO were also normal. Therefore, it would

seem that the failure could not have been caused by the alkali although no other explanation can be offered without a knowledge of the materials used, method employed and weather conditions at the time of fabrication. This information is not available.

The concrete wing wall of a large culvert, shown in Fig. 3, was cited as a case of disintegration due to alkali salts. Upon investigation it was found that there was a bend in the creek at the point where the culvert is located, and during flood the creek carried boulders 12 to 20 inches in diameter which would be thrown against the wall.

FIG. 3.—CONCRETE WING WALL OF CULVERT UNDER IRRIGATION CANAL IN ALKALI DISTRICT

Alkali salts are visible in the pores where the surface is eroded to a considerable depth, but the cement and concrete appears hard and the presence of the alkali would seem to be incidental and contributory rather than the initial cause of disintegration. The composition of the alkali salts taken from the surface was as follows:

Soluble—Calculated on 100 per cent. basis.	Per cent.
CaO	0.91
MgO	.48
Na_2O	41.32
K_2O	trace
SO_3	55.98
Cl	.16
CO_2	trace

In Fig. 4 is shown a large railroad culvert with a portion of an old concrete structure remaining in the foreground. The concrete remaining from the old structure is completely disintegrated so that it can be torn apart with the fingers and alkali salts are found in the pores. The new culvert, which is about eight years old, appears to be sound and normal with the exception of a few spots near the ground line which can be scraped away with a knife. The culvert as a whole does not evidence good workmanship in fabrication.

The surface of the surrounding soil is covered with alkali salts having the following composition:

	Per cent.
Water soluble	8.45
Insoluble	78.35
Loss at 110 deg. C.	13.98

Analysis of water soluble portion:

	Per cent.
CaO	36.16
MgO	.71
Na_2O	5.37
K_2O	.24
SO_3	57.28
Cl	.24

In Fig. 5 is shown a small concrete retaining wall, the coping of which is disintegrated and referred to as a failure due to alkali salts. The surface of the soil surrounding this wall, both at the top and along the sides, shows the presence of alkali salts. The wall is sound and hard at all points examined excepting the coping where disintegration is shown. Since structures are found in the East where no alkali salts are present, which appear just as the one shown with the coping sloughed off due to frost action on a very weak section in the concrete, that results from the use of watery mixtures, it is quite possible that the disintegration of the coping in this structure is due to that cause. In mixtures in which an excessive amount of water is used the fine material in the aggregate and the cement will float to the surface in the forms as they are filled, and collect at the top of the form, resulting in a very porous and weak section which is readily attacked by frost.

It is practically impossible to analyze some of the failures which have occurred and state definitely the part played by the alkali salts, as a result of which it was deemed desirable to make field tests in which concrete of known composition and fabrication would be exposed in some of the worst known alkali districts in the west.

It was decided that this investigation should be started by exposing various cement mixtures in the form of drain tile, because of its economic importance. It will probably become necessary

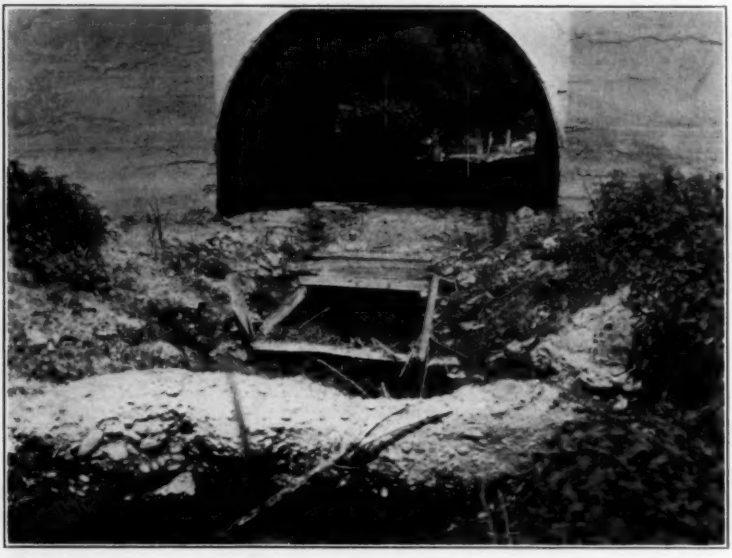

FIG. 4.—CONCRETE CULVERT UNDER RAILWAY ROADBED IN ALKALI DISTRICT.

to drain the greater part of all lands under irrigation, and much of this drainage will require the use of tile. The cost of drainage has been estimated as approximately $25 per acre, from which it is seen that many millions of dollars must be spent for this purpose. At the present time there are few known deposits of clay available for the manufacture of satisfactory clay tile in these districts, while materials for the manufacture of cement tile are usually found close at hand, but many engineers are skeptical of the permanency of cement tile, as a number of failures have occurred which have been reported to have been caused by the alkali salts.

This investigation of cement tile should be followed with an exposure of generous sized blocks of concrete of known composition which would simulate mass construction and would extend from below the surface of the ground or water, in order to determine the possibility of disintegration by the mechanical force exerted by the crystallization of the salts absorbed by capillarity into the pores of the concrete above the water or ground surface. It is anticipated that such an investigation will be conducted.

It is desired to thank the United States Reclamation Service and the several project managers and engineers for their assistance and for furnishing the labor necessary in installing the drains at Montrose, Col., Garland, Wyo., Fort Shaw, Mont., Sunnyside, Wash., and Yuma, Ariz.; the Drainage Division of the Department of Agriculture and their field engineers, for their assistance and for furnishing the labor necessary in installing the drains at Grand Junction, Col., Columbia, Mo., Crookston, Minn., Huntington, Utah, and Roswell, New Mexico; the Iowa State College for providing storage space for a complete set of tile; and P. H. Atwood and the Armstrong Cement Works, Armstrong, Ia., for their hearty co-operation and interest in the manufacture of the tile. Acknowledgment is also made to the Chemical Division, A. N. Finn and G. J. Hough, of the Bureau of Standards, for the chemical analyses of alkalies and disintegrated concretes.

FIG. 5.—CONCRETE RETAINING WALL IN ALKALI DISTRICT.

II. OUTLINE OF INVESTIGATION.

An advisory committee was organized, composed of S. H. McCrory, Chief of Drainage Investigations, Department of Agriculture, F. W. Hanna, Supervising Engineer, of the U. S. Reclamation Service (later succeeded by E. C. Bebb, Engineer, Reclamation Service), L. R. Ferguson, assistant secretary of the Association of American Portland Cement Manufacturers, and Rudolph J. Wig, of the Bureau of Standards. This committee held several meetings and finally developed a program which required the manufacture of about 8800 cement drain tile made up of sixteen different varieties as shown in the schedule below.

TABLE OF SCHEDULE OF MIXTURES AND PROCESSES OF MANUFACTURE OF THE TILE

Series.	Proportions, Cement-Sand.	Consistency.	Manufacture.	Curing.
1	1:2½	Semi-wet	Hand made	Sprinkling
2	1:2½	Quaking	" "	"
3	1:2	Semi-wet	" "	Steam
4*a*	1:2	"	" "	"
5*b*	1:2	"	" "	"
6*c*	1:2	"	" "	"
7	1:3	"	Machine made	"
8	1:4	"	" "	"
9	1:1½	"	" "	Sprinkling
10	1:1½	"	" "	Steam
11	1:3	"	" "	Sprinkling
12	1:4	"	" "	"
13	1:2½	"	" "	Steam
14	1:3	Creamy	Hand made	Sprinkling
15*d*	1:3	"	" "	"
16*e*	1:4	Semi-wet	Machine made	Steam

a = Dipped in neat cement grout, 20-24 hrs. after molding.
b = Dipped in hot tar 6 weeks after molding.
c = 10 per cent ferrous sulphate, by weight, added to mix water.
d = Sand-cement used in place of Portland cement.
e = From factory stock pile. N. W. States Portland Cement. Age probably 6 months when above series were made.

The tile were made as described later under contract at a commercial tile plant, and under the supervision of a representative of the Bureau of Standards. Work was commenced in July and completed in September, 1913, and shipments were made in October, which allowed a curing period of one month for the last tile made. Although it was anticipated that some of the tile of the leaner mixtures which are satisfactory in the humid regions would fail in these alkali soils, the program was arranged to include tile made from the leanest to the richest commercial mixtures.

The tile were installed in operating drains on eight projects in the most concentrated alkali soils available in the West and on projects where there was practically no alkali, for comparison. The location of these projects is as follows:

Alkali Projects.

1. Garland, Wyoming.
2. Fort Shaw, Montana.
3. Huntington, Utah.
4. Sunnyside, Washington.
5. Yuma, Arizona.
6. Roswell, New Mexico.
7. Grand Junction, Colorado.
8. Montrose, Colorado.

Fresh Water Projects.

9. Crookston, Minnesota.
10. Columba, Missouri.

III. MANUFACTURE OF DRAIN TILE.

1. FACTORY AND EQUIPMENT.

The cement test pieces used in this investigation were made at the tile plant of the Armstrong Cement Works, Armstrong, Iowa. This factory has for a number of years been producing large quantities of cement tile varying in size from four to thirty inches for use in northern Iowa.

The factory building consists of a concrete block and frame structure, which houses the mixers and tile-making machines, with a large low-roofed concrete block addition to one side, which is divided into curing chambers. A railroad switch used for the delivery of materials and shipment of the finished product parallels the building on the opposite side.

Sand is received in dump-bottom coal cars and dropped into a pit from which it is drawn by a chain drag to the foot of a bucket elevator. After being elevated the sand is dropped into either of two storage bins, or is carried overhead on a belt directly to a sand storage box, placed above the hopper of a batch mixer. In making commercial tile this hopper is filled with sand to a fixed height, depending upon the proportions desired, and the cement is added.

The gate is then opened and the material passes into the batch mixer, which consists of a cylindrical steel drum mounted on rollers. The interior of the mixer contains scoops or buckets which carry the material up and drop it during rotation. This mixer is very satisfactory in use, mixing the sand and cement uniformly and quickly, but the time required varies considerably, due to the varying amounts of moisture in the sand. A very damp sand generally requires two or three times as many revolutions of the mixer as does a dry sand.

After the cement and sand are thoroughly mixed dry the mass is dropped into another hopper just above a continuous mixer or pug mill. As the dry material is fed into the upper end of the trough of the pug mill, water is sprayed in through a perforated pipe, the amount being regulated by the man at the mixer. To obtain a uniform mixture an experienced man is required, as the rate of feed of the material and the amount of moisture in the sand vary constantly.

This factory is equipped with several tile machines. The one being used in making all the experimental machine made tile was of the revolving packer type, the tile being formed between the stationary metal jacket and the packer which is drawn upwards and out of the tile as it revolves.

The car system is in use for handling the smaller sizes of tile after molding. The equipment consists of a suitable number of three-deck cars equipped with springs and roller bearings, transfer trucks and trackage into the curing chambers and out to the various points in the storage yard.

Steam curing of concrete products is used exclusively for curing the regular output of this factory, but all rooms are equipped with water pipes for sprinkling the product, which was the method desired for several of the series of experimental tile. Cars containing small tile are pushed into low-roofed block-walled rooms, about 90 ft. long, holding eleven cars, with enough clearance on one side to allow a man to pass along the cars and sprinkle the tile. Large tile, wheeled on carts, are cured in two large rooms having concrete floors. Exhaust steam from the engine of an electric lighting plant, owned by the same company, is piped to the various rooms and utilized for curing. Steam was available sixteen hours per day.

TABLE I.—TESTS OF CEMENT AND AGGREGATE USED IN MANUFACTURE OF CEMENT DRAIN TILE.

PORTLAND CEMENT.

Sample Number.	Specific Gravity.	Fineness.		Time Setting.		Soundness			Chemical Analysis.	
		100	200	Init.	Final.	A	W	S		
1	3.16	94.0	77.8	5–45	10–15	OK	OK	OK	SiO_2	22.94
2	3.15	93.8	76.6	5–55	9–45	OK	OK	OK	Fe_2O_3	4.20
3	3.16	94.0	77.0	5–50	9–40	OK	OK	OK	Al_2O_3	4.90
4	3.16	93.6	77.4	5–55	9–35	OK	OK	OK	CaO	62.08
5	3.15	94.4	78.8	5–50	9–00	OK	OK	OK	MgO	1.27
									SO_3	1.64
									Loss	1.57
									Insoluble Residue	0.29

TENSILE STRENGTH IN LB. PER SQ. IN. AVERAGE OF 3 BRIQUETTES.

Sample Number.	7 Days.		28 Days.	
	Mortar.	Neat.	Mortar.	Neat.
1	205	543	290	725
2	200	562	279	711
3	224	517	325	718
4	220	533	308	722
5	257	584	321	647

SILICA CEMENT.

Specific Gravity.	Fineness.	Time of Setting.	Soundness.
2.89	100 mesh. 99.4	Initial... 2–40	OK
	200 mesh. 90.4	Final... 6–45	

Tensile Strength.

7 day mortar.	7 day neat.	28 day mortar.	28 day neat.
180	457	295	537

Chemical Analysis.

	Soluble in HCl.	Insoluble in HCl.
Sil	13.00	31.52
Fe_2O_3	3.46	.....
Al_2O_3	1.40	6.54
Lime	37.78	.....
MgO	1.65	0.59
SO_3	0.87	.....
Loss	2.41	.....

Possible Composition.

	Per cent.
Cement	61.3
Clay and silicious material	38.7

2. MATERIALS.

The cement used in this work was a standard brand of Portland cement, of which approximately 240 barrels were required. For the manufacture of Series 15, a sand cement was supplied by the U. S. Reclamation Service, from the sand cement mill in operation at Arrowrock, Idaho. The results of chemical and physical tests of the cements are given in Table I.

TABLE II.—SAND USED IN THE MANUFACTURE OF CEMENT DRAIN TILE.
(Alkali Investigation)

	1:3 Mortar, 7 day.	Briquettes, 28 day.
Washed sand	282	388
Sand as received	237	348
Sieved to pass No. 20, held on No. 30	191	283
Standard Ottawa sand	205	290

Specific gravity of sand = 2.655.

Granulometric Analysis of Sand.

No.	Per cent passing sieves.
200	0.89
100	1.56
80	5.31
50	18.04
40	27.81
30	46.35
20	67.26
10	84.61
Retained on No. 10	15.38

Uniformity coefficient = 3.30. Per cent of silt = 3.9.

The sand used was shipped in from Mason City, Iowa, being the material regularly used in the factory. Analysis and tests are shown in Table II.

The water was pumped from a well at the factory.

Power was furnished to the entire equiment by a 20 H. P. electric motor, receiving current from the electric lighting plant.

3. MACHINE-MADE TILE.

These tile, made on the cement tile machine, are $12\frac{1}{4}$ in. in length, $\frac{3}{4}$ in. thick, with an inside diameter of 8 in.

Sand was brought to the proportioning hopper as stated above, except that it was first dropped into a large box, placed on a platform scale on the upper mixing platform. All proportions were determined by weight, every batch of sand used being weighed and then dropped in the hopper above the batch mixer where the cement was added. The material was then dropped into the batch mixer, which revolved continuously, the slide of the hopper again closed, and another batch of the material prepared. Usually one batch would be passing through the pug mill, a second being mixed in the batch mixer and a third being prepared in the proportioning hopper so that the pug mill could be operated continually to its full capaciy.

Usually one man can prepare the batches and keep the pug mill hopper filled, but on account of the extra labor caused by the weighing of the sand, two men were used while the "machine" tile were being made. Two men were also required to regulate the water supply and shovel the mixed material into the elevator boot of the tile machine.

One man is required to operate the machine, two men are used in stripping jackets from the tile, which were placed on the car decks only a step or two away from the machine, one man is required in the sand pit and another to push out loaded cars and bring back the empty cars, so that a total of nine men were required to operate the machine at its highest efficiency.

The quantity of water required for various batches of each series was measured by passing the water supply through a barrel whose contents were known for each inch in depth. The amount was then determined by measurement.

Due to the variation in the amount of moisture in the sand and to the use of a continuous mixer in which the water was added, it was impossible to add a predetermined or fixed quantity of water to every batch of dry material. In every case an attempt was made to make the mixture as wet as possible and still allow the immediate removal of the jacket. Too small or too great an amount of water in case of the lean mixtures will cause the tile to crumble or crack in removing the jacket, or collapse during the shifting of the car. A rich mixture containing a small excess of water will usually hang together, due to the "stickiness" of the cement, but it is likely to be distorted unless the jacket is stripped with unusual

care. Too little or too much water will usually cause immediate trouble at the machine, greatly cutting down the output. The proper amount is indicated very plainly by the web-like markings of neat cement on the outer surface of the tile.

The cars in use hold 97 8-in. tile, but usually the number of good tile was less, due to the sorting out of the culls, which were caused either by the failure of the machine to work properly or by carelessness on the part of the strippers in removing the jackets. This loss can be avoided and the green material remolded if the damaged tile are removed at once.

After placing in the curing room, the tile were sprinkled twice, if to be steam cured, once in the evening of the day made and again during the following morning, steam having been turned on during the night. The steam-cured tile were exposed to steam for a total period of 96 hours, 16 hours per day, after which they were piled in the storage yard. The water-cured tile were sprinkled twice daily for a period of 12 days and then removed and piled in the storage yard.

The temperature of the moist air in the curing rooms varied from 110 to 120 deg. F. during the period in which the steam was on.

The water-cured tile were allowed to harden under much more favorable conditions than are usually understood by the term "water curing." Too often "water cured" means that tile are stored in an open shed or at best in a large room containing many doors and windows, and sprinkled one or more times a day. In the case of these experimental water-cured tile, the cars were run into the long, narrow curing rooms which are continually damp, with wet floors, and perfectly protected from the sun and air currents. The amount of evaporation under these conditions is small compared to that in a large room or shed.

4. HAND-MADE TILE.

The hand-made tile were made of two types, the semi-wet series and the wet series. These tile have an inside diameter of 8-in. with smooth walls $1\frac{1}{2}$ in. thick and $12\frac{1}{4}$ in. long, made in sheet metal molds provided especially for this work. The great difficulty in the use of such molds is in keeping the core centered so that the walls of the resulting tile will be of uniform thickness.

Several methods were tried to secure the proper results and the one found simplest and most satisfactory consisted of a wooden base with two concentric circles of small headless nails projecting up about $\frac{3}{8}$ in. above the boards. These nails were placed on the inner and outer circumference of two circles having diameters of 8 and 11 inches, respectively. This arrangement provided for the centering of the lower end, but it required careful use of the tamping iron to obtain a uniform wall thickness at the top. Molds made of heavier metal would be more satisfactory in this respect but the cost would have been excessive for this experimental series.

The process of proportioning and mixing of the materials up to the addition of the mixing water was in every way similar to that of the machine-made tile.

Series 1, 3, 4, 5 and 6 were of the semi-wet consistency, containing as much water as would allow the immediate removal of core and jacket. However, it was found that the material for these hand-made tile had to be slightly drier than that which could be used on the machine, probably due to less pressure being exerted in hand tamping, making the tile less dense.

The semi-wet hand-made tile were molded on the concrete floor of one of the large curing rooms and were sprinkled in the evening of the day molded. The following morning they were again sprinkled and then placed on cars and shifted into the low-roofed curing rooms, where the steam or water treatment was continued for the proper length of time. In the manufacture of Series 6, 10 per cent of ferrous sulphate, by weight, was added to a known weight of water in the measuring barrel and this solution, kept well stirred, was used in mixing.

The tile of Series 14 and 15 were made of a much wetter consistency than those of the other series. These tile contained sufficient water so that they could be easily poured into the mold from a small bucket. The tamping iron was used along the walls of the mold to aid in removing air bubbles from the surfaces. The tile of Series 2 were of an intermediate consistency, and required considerable tamping in small layers, in order to prevent the formation of "rings" or roughened surfaces. The tile of these series were piled in one of the long curing chambers and sprinkled twice daily for at least ten days.

5. CONSISTENCY OF MIXTURES USED.

The following consistencies were used in the manufacture of the tile:

Semi-wet.—As much water was added to the dry mortar mixture as would permit the immediate removal of the jacket from the tile. This condition is indicated by the web-like marks of neat cement and water on the outer surface of the wall. This consistency was used for making the tile of Series, 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 16.

Quaking.—Moisture could easily be brought to the surface by tamping. The material would settle about $\frac{3}{8}$ in. in the mold during the first two hours after molding. This consistency was used for making the tile of Series 2.

Creamy.—This material was of such a consistency that it could be easily poured into the mold. It would settle $\frac{1}{2}$ to $\frac{3}{8}$ in. in the molds during the first four hours after molding. This consistency was used for making the tile of Series 14 and 15.

6. DETAILED DESCRIPTION OF EACH TYPE OF TILE

Following is a description of the tile of each of the various series, together with any notes on manufacture peculiar to each:

Series 1.—Proportions, by weight, 1 part Portland cement to $2\frac{1}{2}$ parts sand, semi-wet consistency, hand tamped and cured by sprinkling. An average of 7.7 tile was obtained from each bag of cement.

Series 2.—Proportions, by weight, 1 part Portland cement to $2\frac{1}{2}$ parts sand, quaking consistency, hand tamped, cured by sprinkling with water. An average of 7.2 tile was obtained from each bag of cement.

Series 3.—Proportions, by weight, 1 part Portland cement to 2 parts sand, semi-wet consistency, hand tamped, stored in air for first 24 hours, than a total of 102 hours in steam. An average of 7.6 tile was obtained from each bag of cement.

Series 4.—Proportions same as Series 3. Cured 24 hours in air, then dipped in neat cement grout, loaded on cars and exposed to steam for a period of 102 hours. An average of 6.9 tile was obtained from each bag of cement, allowing for cement required for grouting.

Series 5.—Proportions and method of curing same as Series 3. Tile then stored in yard and dipped in boiling tar when 6 weeks old. An average of 7.2 tile was obtained from each bag of cement.

Series 6.—Proportions and method of curing same as Series 3, except that 10 per cent of ferrous sulphate, by weight, was added to mixing water. An average of 7.0 tile was obtained per bag of cement.

Series 7.—Proportions, by weight, 1 part Portland cement to 3 parts sand, semi-wet consistency, machine made, steam cured. These tile were loaded on cars and placed in the curing chambers immediately after making. Steam was turned on within a few hours and continued for a total period of 96 hours. An average of 14 tile was obtained per bag of cement.

Series 8.—Proportions, by weight, 1 part Portland cement to 4 parts sand, semi-wet consistency, machine made, cured in steam for a total period of 96 hours. An average of 18.8 tile was obtained per bag of cement.

Series 9.—Proportions, by weight, 1 part Portland cement to $1\frac{1}{2}$ parts sand, semi-wet consistency, machine made, cured by sprinkling with water for a period of 12 days. An average of 8.7 tile was obtained per bag of cement.

Series 10.—Proportions, by weight, 1 part Portland cement to $1\frac{1}{2}$ parts sand, semi-wet consistency, machine made, cured in steam for a period of 96 hours. This series differs from Series 9 only in the method of curing. An average of 8.7 tile was obtained per bag of cement.

Series 11.—Proportions, by weight, 1 part Portland cement to 3 parts sand, semi-wet consistency, machine made, cured by sprinkling for a period of 12 days. This series differs from Series 7 only in the method of curing. An average of 13.7 tile was obtained per bag of cement.

Series 12.—Proportions, by weight, 1 part Portland cement to 4 parts sand, semi-wet consistency, machine made, cured by sprinkling for a period of 12 days. This series differs from Series 8 only in the method of curing. An average of 18.4 tile was obtained per bag of cement.

Series 13.—Proportions, by weight, 1 part Portland cement to $2\frac{1}{2}$ parts sand, semi-wet consistency, machine made, cured in steam for a total period of 96 hours. An average of 12 tile was obtained per bag of cement.

Series 14.—Proportions, by weight, 1 part Portland cement to 3 parts sand, creamy consistency, hand tamped, cured by sprinkling for a period of at least 12 days. Greater part of settling of material in molds took place during the first hour after which the molds were refilled with some of the same material, tamped and troweled. An average of 8.0 tile was obtained per bag of cement.

Series 15.—Proportions, by weight, 1 part sand-cement to 3 parts sand, creamy consistency, hand tamped, cured by sprinkling with water for a period of at least 10 days. Molds refilled with same material, tamped and troweled, after settling had taken place. These tile required very careful handling when the molds were removed on the day after molding to avoid breakage. An average of 7.4 tile was obtained per bag of cement.

Series 16.—Proportions, by weight, 1 part Northwestern States Portland cement to 4 parts sand, semi-wet consistency, machine made, cured in steam. This series, which was taken from the stock pile of the Armstrong Cement Works, represents the regular commercial output of this factory. No especial care was used in selection, except to throw aside tile which were cracked or had jammed ends. The exact age of this series is uncertain, but the tile are probably at least six months older than those of the preceding series.

The machine-made tile varied in weight from 23 to 25.25 lb. averaging 24 lb.; the semi-wet hand-tamped tile varied in weight from 42.25 to 45 lb., averaging about 43.2 lb.; tile in Series 15, sand-cement, averaged about 41.5 lb.

The difference in appearance of the surfaces of the different series is shown in Fig. 6 to 9. The appearance varies with the richness of the mixture as well as the method of molding. Of the machine-made Series 9 and 10, the richest, are lightest in color with more of a glazed appearance, while the leaner mixtures are darker in color and have more of a sandy, roughened appearance. In the hand-made Series, No. 15 is nearly white with a "chalky" appearance due to the use of sand cement. Series 2, 14, and 15, the hand-made tile of wet consistency, have rather smooth surfaces with numerous small and shallow indentations due to air pockets on the walls of the molds. The semi-wet

mixtures in the hand-made tile have rough surfaces as a rule and in a few cases irregular and insufficient tamping was indicated by the appearance of circumferential rings of porous appearing concrete.

Throughout this work no departure from the regular pro-

FIG. 6.—HAND- (SERIES 2) AND MACHINE-MADE (SERIES 7) TILE, SHOWING THE TEXTURE OF THE SURFACES.

cesses in use at this plant were made except that the proportions were varied and all the materials were weighed to insure uniformity. No specially chosen aggregates were used, the sand being that used in the factory for the manufacture of all kinds of cement products, and the cement being purchased under bids with the

requirement that it was to pass the United States Government specification for Portland cement. Although some of the mixtures contain more cement than those in ordinary commercial use, and it is not practicable to make a hand-made tile which can

FIG. 7.—MACHINE-MADE TILE OF THE RICHEST AND LEANEST MIXTURES, SHOWING THE TEXTURE OF THE SURFACE.

compete in price with the usual machine-made tile, any well-equipped and managed factory using good materials should be able to turn out a product which is as good in every respect as has been provided for this investigation.

IV. INSTALLATION OF DRAIN TILE.

1. SHIPMENT.

Shipments of the tile from the factory at Armstrong, Iowa, were made early in October, 1913. A car-load (about 780 tile)

FIG. 8.—TILE MADE OF CREAMY (14), QUAKING (2) AND SEMI-WET (1) CONSISTENCIES, SHOWING CHARACTER OF SURFACES.

was shipped to each project, each shipment consisting of fifty tile of each series, with the exception of Series 5 and 15, of which 45 and 36 respectively were sent. The tile were piled on their sides in rows with the walls parallel to the car sides, beginning at

either end, and tiered three and four high, depending upon the length of the car. This arrangement was continued up to within three feet of the doorway, where the number of layers was reduced to two and then one. The doorway space was occupied by several rows one tile high, placed so as to block the lower layer in the two

FIG. 9.—SHOWING TEXTURE OF THE SURFACE OF THE TILE MADE WITH SAND-CEMENT (SERIES 15), FERROUS SULPHATE (SERIES 6), TAR-DIPPED TILE (SERIES 5) AND CEMENT GROUTED TILE (SERIES 4).

ends. To reduce the breakage, a thin layer of straw was spread over the floor and between the layers. The cars arrived at their destination showing little evidence of the tile having been thrown out of place while in transit, although no framing whatever was used to keep them in position. Breakage was due almost entirely

to wedging of tile in the lower layers. This wedging action was probably aided by the "giving" of the car sides while in motion. In some cases no record of breakage was kept at the time of unloading, so that the following figures include the loss in unloading and hauling of the tile at destination.

The length of wagon haul and the total breakage was as follows:

Location.	Length of Wagon Haul.	Loss.
Garland	3½ miles	3
Fort Shaw	1 "	3
Huntington	24 "	18
Sunnyside	1½ "	8
Yuma	2 "	18
Roswell	5 "	4
Grand Junction	2 "	9
Montrose	12 "	22
Columbia	1½ "	22
Crookston	800 yards	6
Ames	400 feet	3

A total of 115 tile were broken, out of over 8500 which were shipped an average railway haul of about 1300 miles and a wagon haul of over 4.5 miles. The average loss by breakage is 1.3 per cent.

2. COMPOSITION OF ALKALI AND SOIL AT DRAIN SITES.

Samples of soils were obtained at all projects and of alkalies and waters where available for analysis.

3. PLACING.

The tile were placed in such an order that sections containing two tile of each series could be removed at yearly intervals without disturbing the remainder of the line. Ten such sections, 32 ft. long, were placed at one end of the line, and then all the tile remaining of each series were placed end to end in groups commencing with Series 1. This grouping is shown in Fig. 10. At Garland, Fort Shaw, Sunnyside, Yuma and Roswell, the "A" sections were placed at the upper end of the drain and the "B" sections at the outlet end. At the other points this arrangement of sections was reversed.

(a) Garland, Wyoming.

The drain was placed about three and one-half miles southeast of Garland in a low section where alkali stood in layers an

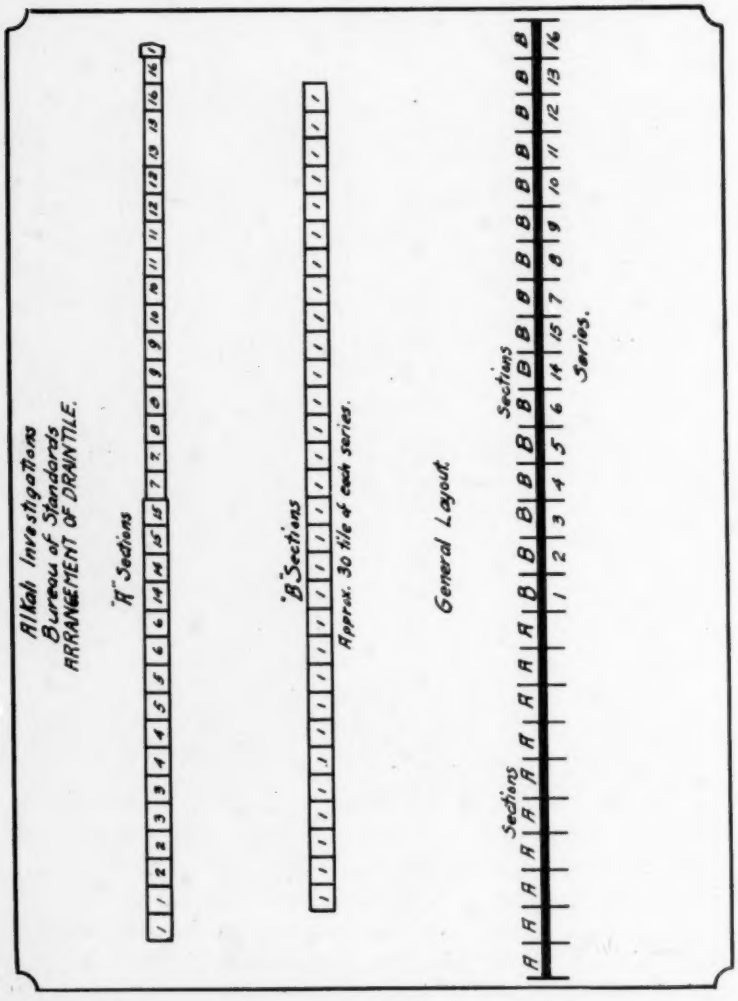

FIG. 10.

inch or more in thickness on the ground. Several concrete turnouts located nearby in unused ditches were entirely disintegrated. As shown in Fig. 11 the lower end of the drain runs through a

sandy soil and the upper end through coarse gravel, the grades being .022 and .010 respectively. The outlet is in an open ditch

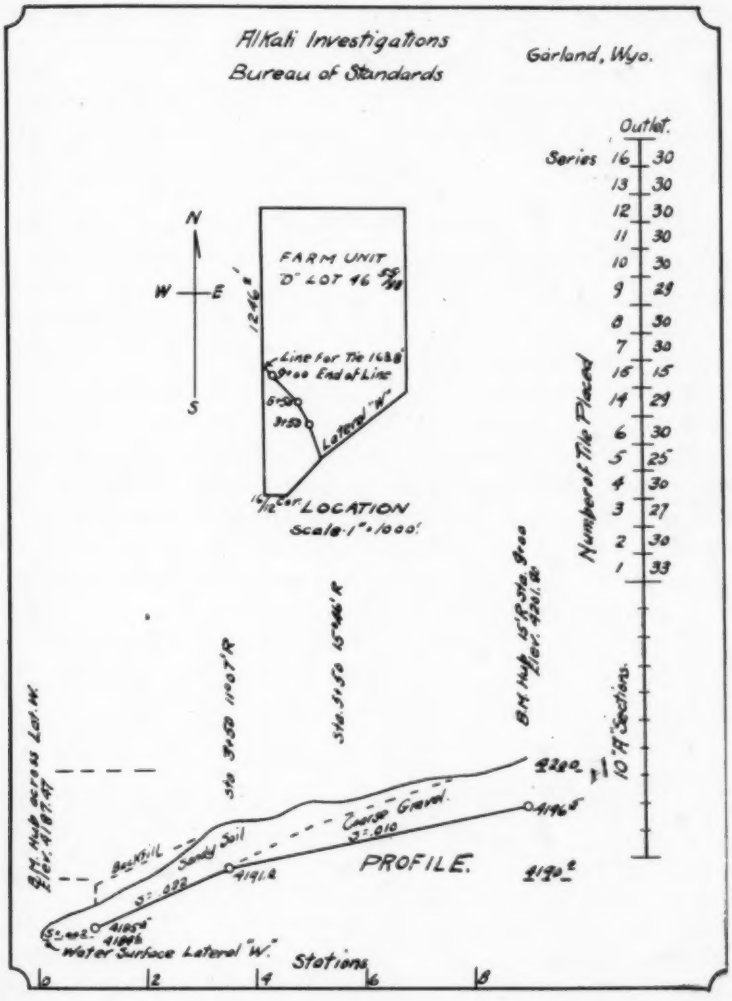

FIG. 11.

which has a grade of .002. Since the outlet end for a distance of 200 ft. lies above the frost line, a backfill was made, giving a minimum covering of four feet.

The tile were laid in cradles made of 2 x 4-in. side pieces and 1 x 4-in. cross pieces on which the tile rested. Manholes were placed at Stations 3+50 and 4+50, at an angle point and change of grade. At the time the tile were placed the ground water plane was at the surface of the ground for the entire distance. The total fall in the line is 11 ft. Only three tile were broken or missing at Garland, the number being unusually low considering the length of the haul.

(*b*) *Fort Shaw, Montana.*

At Fort Shaw a location for the tile line was found just above an alkali lake where the tile would also be of some service in draining an upper swamp, which had ruined several farm units. The surface of the ground surrounding the lake and the site of the drain was encrusted with alkali $\frac{1}{8}$ to $\frac{1}{4}$ in. in thickness. Wooden silt boxes were placed at the upper end and at Station 6+00, where an angle was made. As the greater portion of the drain was located above the frost line, the refill was made to a depth of four feet wherever the cut was less than this amount. A portion of the line passed through hard cemented gravel which gave considerable trouble in digging. The upper 400 ft. of the line was given a grade of 0.021 and the lower 200 ft. a grade of 0.004, the outlet being into an open ditch which emptied into the alkali lake 200 feet below the tile line. Three tile were broken in this shipment. Fig. 12 shows the location of this drain.

(*c*) *Huntington, Utah.*

At Huntington the tile drain was installed on private land about one mile south of town. Wooden box drains, without bottoms, had been placed in this ground about eight years before, and as these boxes were badly off grade, it was decided to replace them with cement tile.

As shown in Fig. 13, the line of the old wooden drain was not closely followed, but an offset was made and the old line paralleled. The trench varied in depth from $4\frac{1}{2}$ to 6 ft. passing through a soil uniform in color and appearance, and acting much like quicksand in the bottom, due to the excess of water. The digging was very easy, requiring no picks or spades, but only round-pointed, long-handled shovels. Due to the comparatively shallow

depth of the outlet and to the small natural slope of the land, it was necessary to place the line with a very slight fall, which prob-

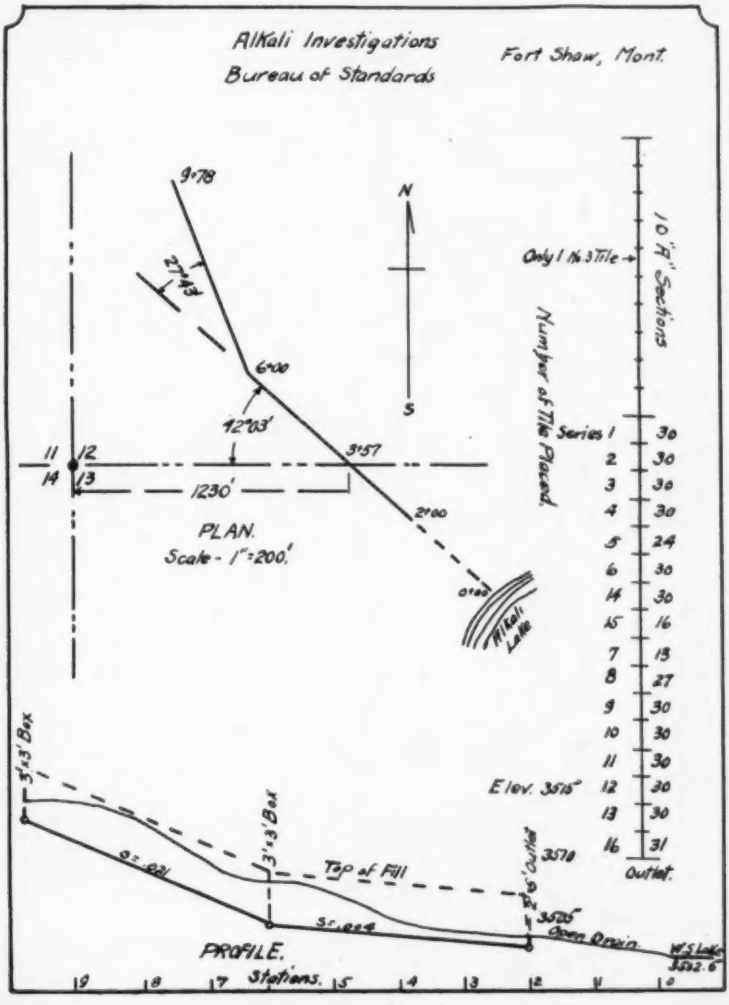

FIG. 12.

ably did not exceed 0.1 ft. per 100 ft. In the portion of the trench which followed the old box drains the tile were supported on boards 1 in. x 6 in. x 12 ft. on account of the soft bottom.

On account of rains preceding the installation of the experimental tile, the white surface of this and the surrounding land

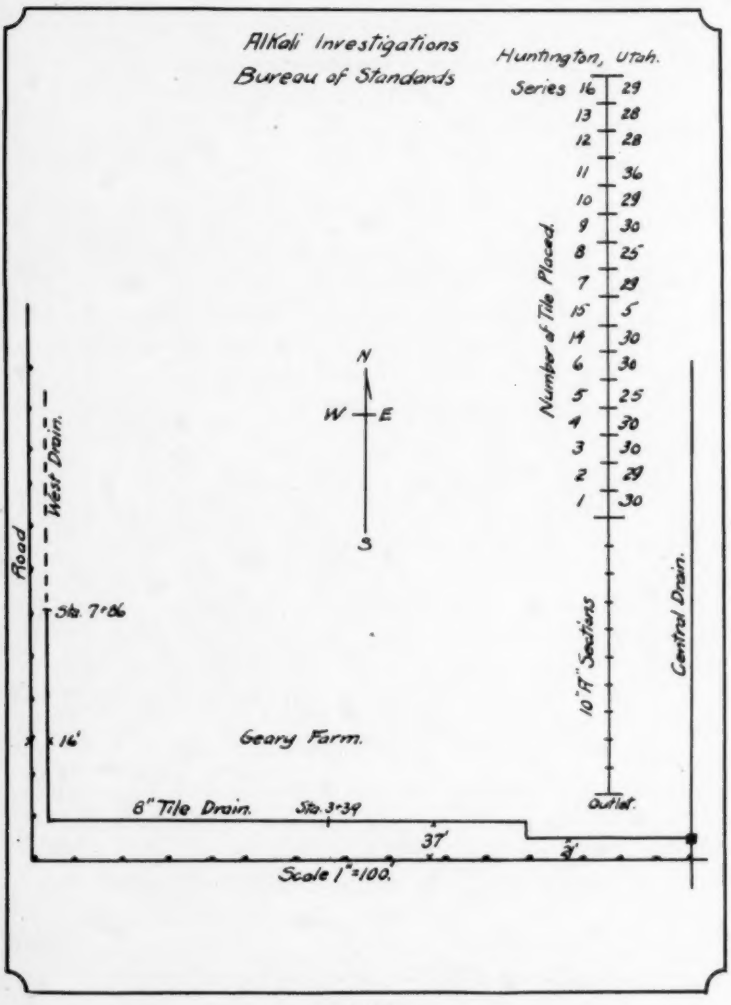

FIG. 13.

was not so apparent, but in spots, large white patches could be seen. Land to the west and slightly higher than that on which the tile were placed was very wet, and sandstone boulders lying

on the surface were badly cracked and disintegrated, apparently due to the crystallization of the alkali in their pores.

As Huntington is located about 23 miles from the railroad,

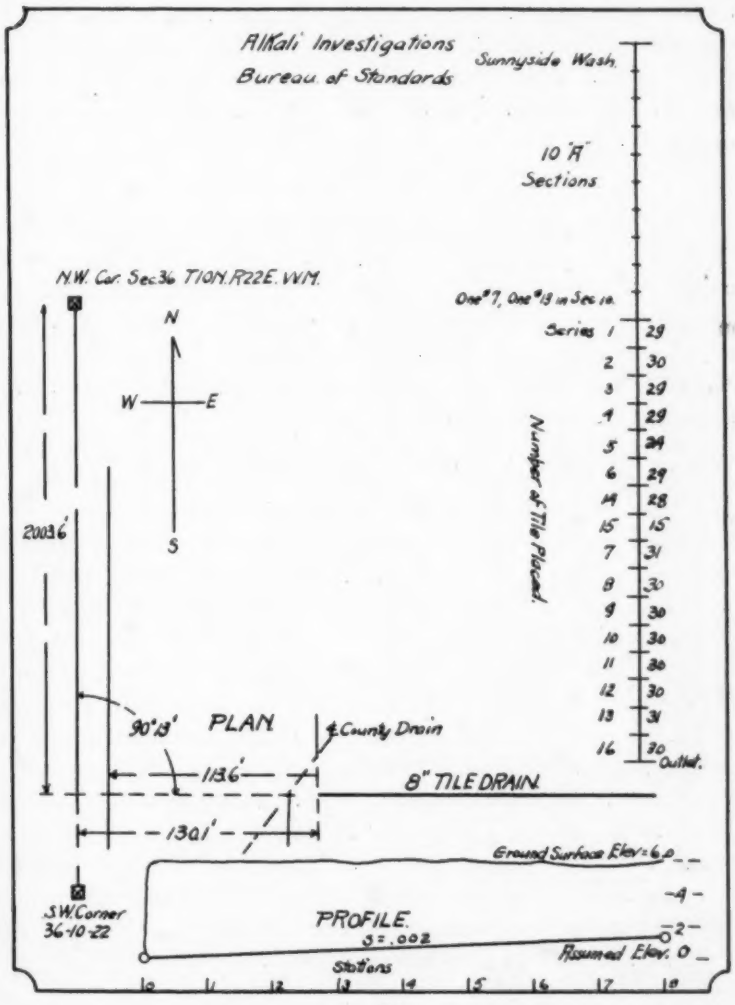

FIG. 14.

it was necessary to haul the tile from Price, Utah. The number of tile broken was 18, confined mostly to the handling on the railroad, as only 4 tile were broken in the 24-mile haul from Price.

(*d*) *Sunnyside, Washington.*

At Sunnyside the tile were installed on private land about one mile from town. The trench at the lower end was about 6 ft. deep and 4½ ft. deep at the upper end. At the lower end the soil was very sandy. The water table was low at the time the tile were placed. A uniform grade of .002 was used. There was a loss of 8 tile in this shipment. The location of this drain is shown in Fig. 14.

(*e*) *Yuma, Arizona.*

The installation at Yuma was made in the southeast corner of the Experiment Farm of the U. S. Department of Agriculture, on the Yuma Indian Reservation. The drain follows the line of an old slough and is exposed to concentrated alkali water. The wagon haul to this point was about two miles and the total number of tile lost, including railroad breakage, was eighteen. Fig. 15 shows the location of this drain.

(*f*) *Roswell, New Mexico.*

The installation at Roswell was made on private land 4 miles east and 1½ miles north of Roswell on the northeast quarter of Section 25, T 10 S, R 24 E, N.M. Principal Meridian, Fig. 16.

The outlet of the line was placed in the wooden manhole of a drain which had been previously constructed and extended northeast in a straight line with a uniform rise of .1 ft. per 100 ft. The depth averaged about 6.5 ft. with the exception that the upper 150 ft. had a depth of about 5.5 ft. During the installation, the ground water stood about 4 ft. above grade, causing the sides of the trench to cave unless well braced. A wooden manhole was placed at the end of the tenth "A" section, and an observation well at the upper end of the line. Three tile were found broken in the car and one was broken in hauling to the drain site, so that the breakage was approximately one-half of one per cent. Fig. 17 shows the work in progress at Roswell.

(*g*) *Grand Junction, Colorado.*

The tile at Grand Junction were placed on a ten-acre tract of land included in the McKinney Experimental Farm, ¼-mile south of the old U. S. Indian School, just east of the city (Fig.18).

The land of which this tract is a part is being improved under the supervision of Drainage Investigations of the Department of

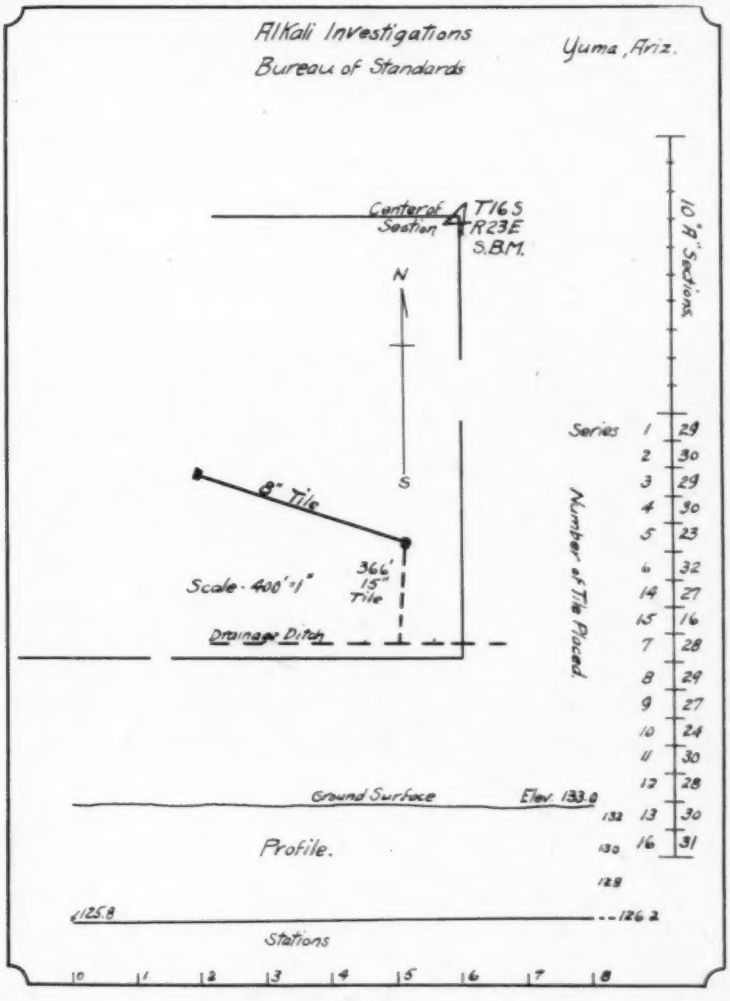

FIG. 15.

Agriculture. This land had previously been irrigated and cultivated, but was later abandoned on account of the concentration of alkali on the surface and in the upper part of the soil. At the

time the experimental tile were placed the surface was entirely covered with a thick white coating of alkali salts as shown in Fig. 19.

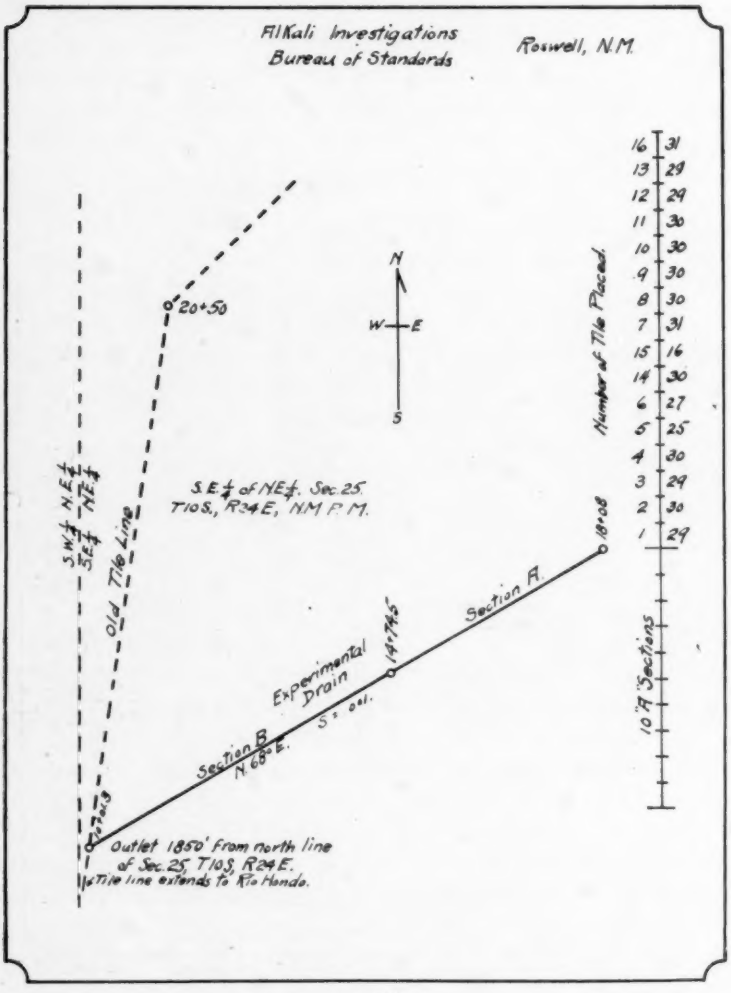

FIG. 16.

The trench was excavated to a depth of $5\frac{1}{2}$ to $6\frac{1}{2}$ ft., the lower portion being very wet and mucky, requiring heavy sheeting and bracing which interfered greatly with the work of excavation and

made progress very slow. The tile were laid on a grade of 0.3 ft. per 100 ft.

The drain empties into a large wooden silt basin which is a part of the system of drains of an adjacent ten-acre tract. Although the line is straight, without bends, another basin was placed at the end of the tenth "A" section and also one at the upper end to aid in observing the working of the drain.

The total breakage in this shipment was nine tile, four being found broken while unloading the car.

FIG. 17.—VIEW FROM LOWER END OF OPENED DITCH, FOR EXPERIMENTAL DRAIN, ROSWELL, N. M.

(*h*) *Montrose, Colorado.*

The point selected for placing the tile was about twelve miles from Montrose on "seep" land near mile-post No. 6 and below the level of the South Canal on the Uncompahgre Project of the U. S. Reclamation Service. The soil consists of adobe and shale. This shale becomes very hard when dry and is difficult to excavate. The upper end of the tile line was entirely through shale. The amount of water flowing in the bottom of the trench was small, being as great near the upper end as at the outlet, indicating that

most of the seepage occurs through the shale. Seepage was small in amount because the canal had been emptied previous to the

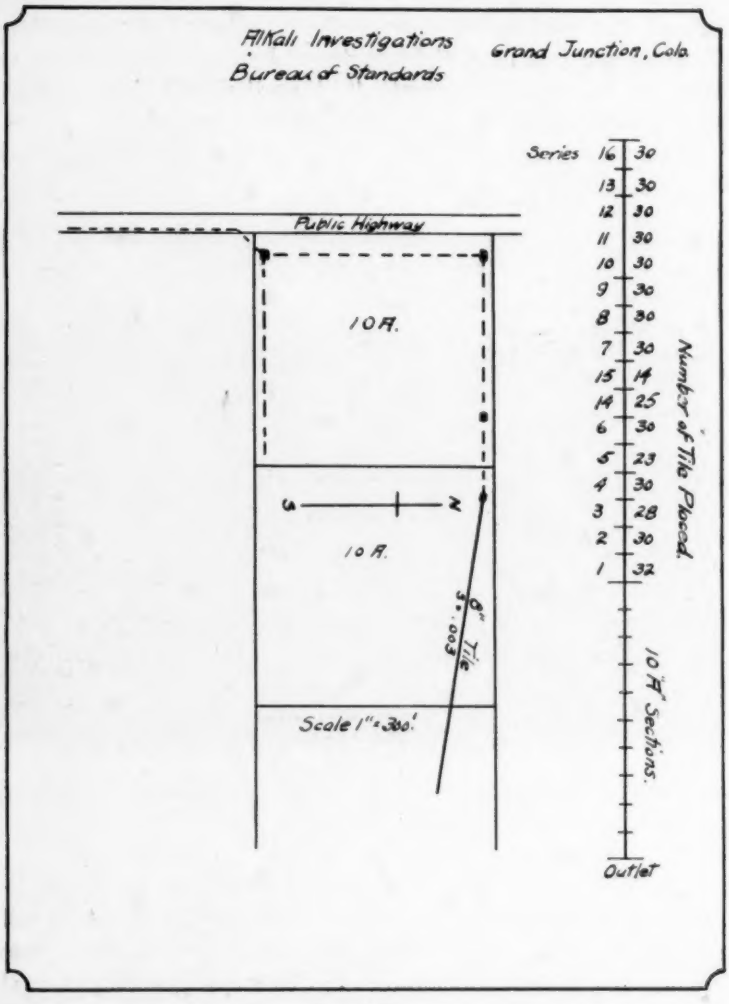

FIG. 18.

excavation of ditch for the experimental drain, but during the summer months the seepage should be considerably increased, as the change from concrete lined to the unlined canal, whose

maximum capacity is 1300 sec.-ft., is made opposite the upper end of the tile line.

The breakage of tile at this point was the maximum, 22 tile being damaged in the railroad and wagon haul. A 12-ft. wooden box was placed at the outlet and wooden silt boxes at the two angles, at Stations 2+60 and 5+35. From Stations 1+92 to 2+42 and 2+75 to 3+07 the tile were laid on boards in the bottom of the trench. The location of this drain is shown in Figs. 20 and 21.

FIG. 19.—VIEW OF SITE OF EXPERIMENTAL DRAIN, GRAND JUNCTION, COL.

(*i*) *Columbia, Mo.*

The experimental drain at Columbia was placed on land belonging to and being farmed by the University of Missouri Agricultural School, about one-half mile south of the campus. The line, which has a total fall of about 24 ft., follows the line of a small channel which has been cut by surface water. The depth of the tile below the surface is small, as shown in Fig. 22, but it is sufficient to protect the line from frost action. The upper 12 or 15 in. is black soil and rather easy to dig, with the exception of a short length through the ridge at Station 2+00, where some rocks were

found. The soil was moist, but no stream of water was developed during the trenching. A wooden box outlet was placed at the lower end where the earth covering was shallow.

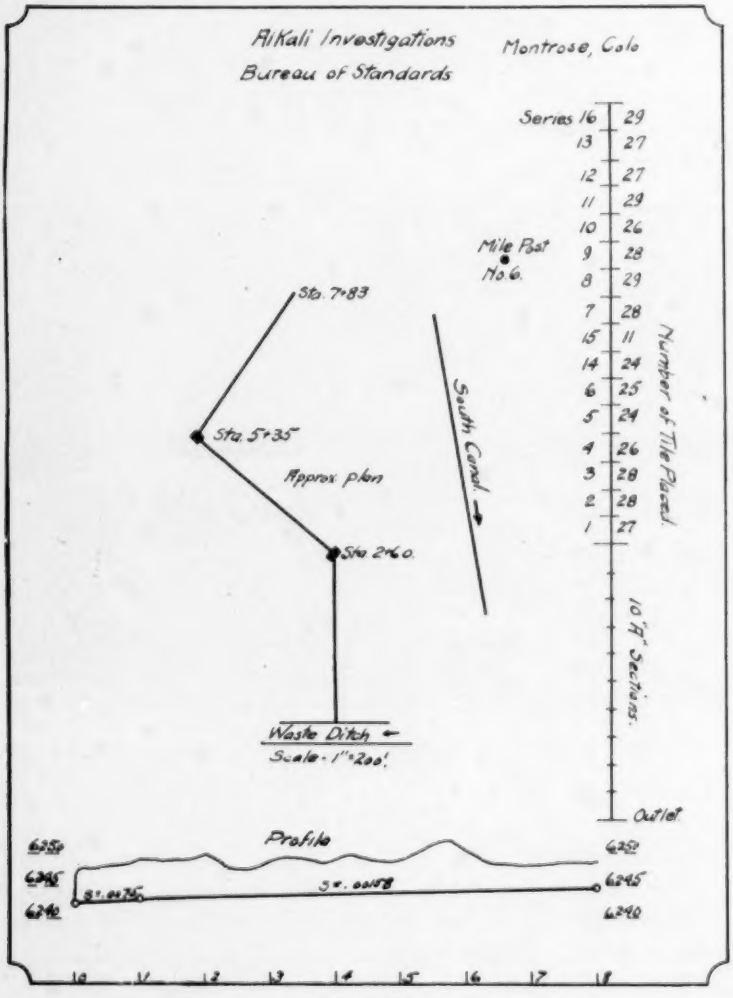

FIG. 20.

The total breakage in the shipment of tile to this point was 22.

(j) Crookston, Minn.

The tile shipped to Crookston were installed in a forty-acre tract of pasture land which is part of the land belonging to the "Northwest Agricultural School" of the University of Minnesota, which is located about 1½ miles north of Crookston. This region is very flat and has very little natural surface drainage, being made up mainly of small ridges and depressions varying only a few feet in elevation. The flatness of the country, which is farm, is one of the lowest areas, is shown by the result of a topographical

FIG. 21.—VIEW FROM UPPER END OF SITE OF EXPERIMENTAL DRAIN, MONTROSE, COL.

survey, which indicates that in the 476 acres included in this farm the greatest difference in elevation is about 2 ft.

The soil is mainly a clayey loam, the upper few inches being black, the lower sections yellow, but of about the same composition. The black soil appears to be deeper in the depressions. Scattered deposits of alkali salts can be found in the elevations. At the time the trench was dug the soil was quite moist and sticky and was removed from the spade with difficulty. The lower foot was harder and drier and even more difficult to dig.

As shown in Fig. 23, the tile was placed quite shallow with a uniform fall of 0.8 ft. in the length of 800 ft. A wooden box

emptying into an open ditch was placed at the outlet (Fig. 24). There was no flow of water at the time the tile were installed.

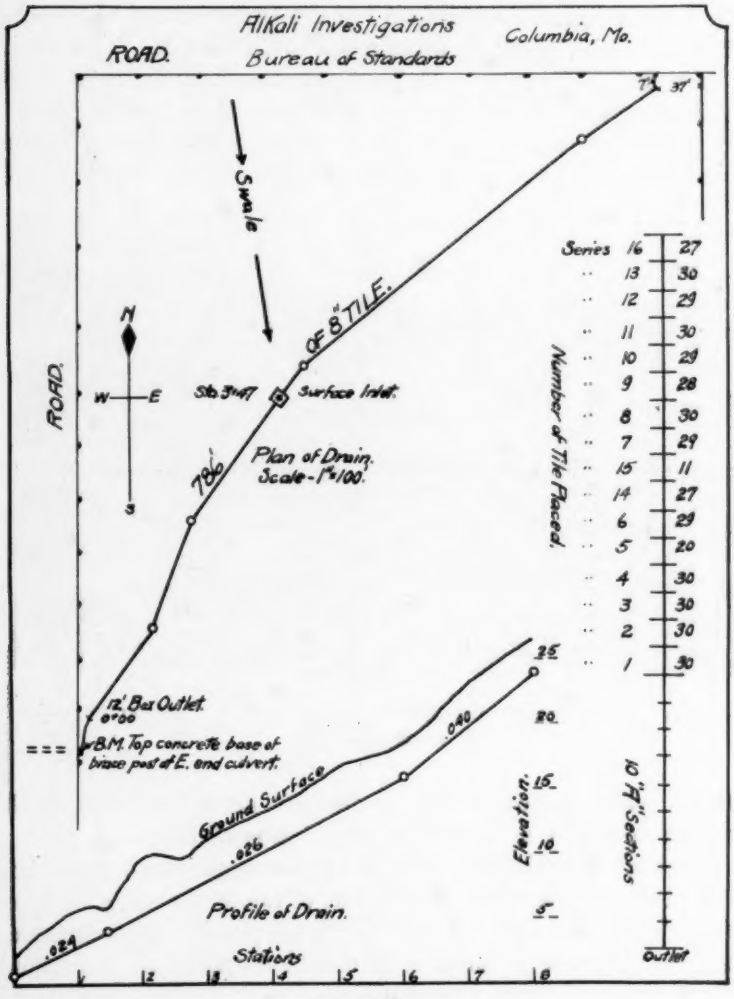

FIG. 22.

The total breakage in tile in this shipment amounted to 6, of which 3 were broken in being hauled to the ditch.

(*k*) *Ames, Iowa.*

A car containing 48 tile of each series excepting Series 15, of which there were only 42, was shipped to the campus of Iowa

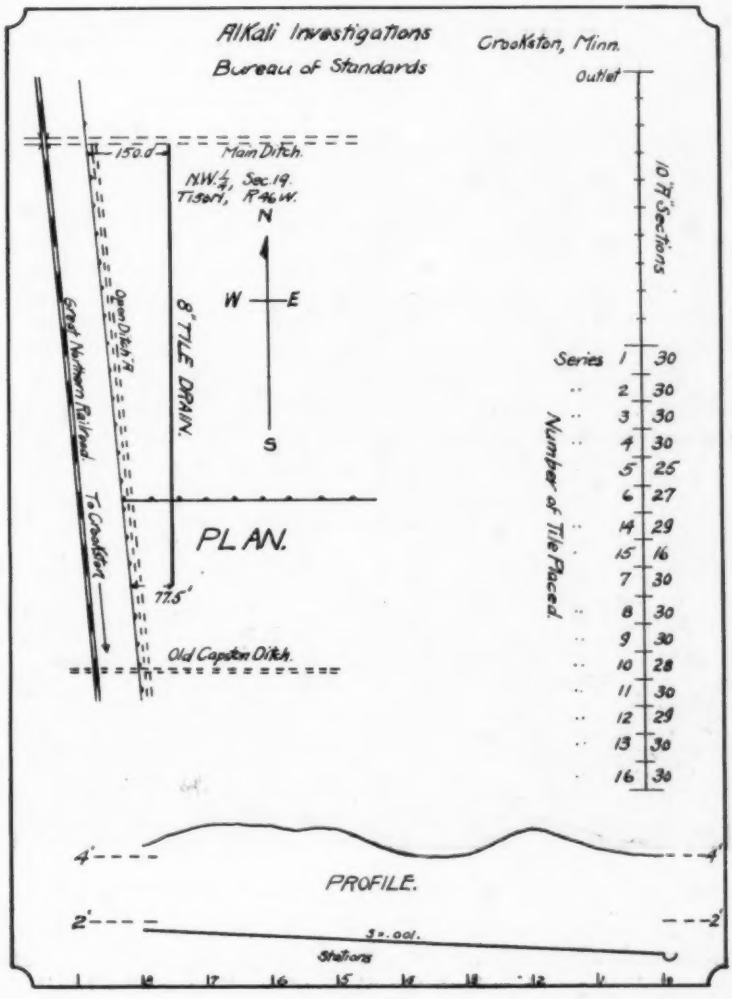

FIG. 23.

State College, Ames, Iowa, for storage. These tile were piled on wooden strips so as to keep them above the surface of the ground.

A more careful account was made of the breakage here than had been made of the previous shipments. Although no packing of any kind was used and the tile were piled to a height varying from four high at the ends to two high at the doorway of the car, only

FIG. 24.—LOWER END OF EXPERIMENTAL DRAIN, CROOKSTON, MINN.

3 tile were broken. When the car was opened the tile were found arranged just as placed at the time of loading. The breakage was confined to the lower layers near the car sides, indicating that the damage was due to the wedging of the tile, caused by movement of the car sides.

CONCLUSIONS.

No physical tests of the tile will be made until the fall of 1914, and of course, no prediction of the results can be made, but it is believed that the results of this investigation will give reliable information on the possibilities of using cement tile and concrete work in general in localities where alkali conditions are severe. The localities selected for this investigation are in most cases probably as badly effected by alkali as could have been found, and if the results indicate that alkali has little effect on well-made cement tile, the reclaiming of large areas of valuable land will be materially cheapened, since materials for the manufacture of a good quality of cement tile are available in most sections of the West. It will also establish the probable durability of all types of concrete structures exposed to alkali waters.

SOME ESSENTIAL REQUIREMENTS IN CONCRETE PAVEMENTS.

By R. C. Stubbs.*

In the laboratory, much care is taken to conserve every value that is placed in a concrete specimen. Many contractors are inclined to feel that when they have stood watch and fulfilled the task of assembling material, mixing and placing concrete, that they have finished. This is far from the fact. This work is only the beginning of a concrete operation; conditions are made favorable for the real agent, the silent worker "chemical action," which work will be complete in proportion to the manner in which they have done their part.

This discussion will be limited to concrete when used for street or road pavement, and it is desired to call attention to what have been found to be small and often neglected but important points. The following are most often underestimated, and if there is failure, it can be traced to the neglect of one of these: density, contraction, sub-grade, protection.

Density.

Notwithstanding there is much importance in the well known theme of gradation of aggregate, this is not the most important. Care must be taken in placing and the use of the proper amount of water. It is not difficult to calculate and prepare the mixture that will contain the least voids. On the other hand, it is just as easily shown that this perfectly balanced mixture can be made to contain maximum voids, simply by adding surplus water. Water gauging is too imperfect; slight variations in size of batch, in combination with the hit and miss mechanism of water gauges, are sufficient to produce a different amount of water for almost every batch, notwithstanding the importance of this feature.

For example: If a specimen be taken from a properly mixed and gauged mixture, and 4 per cent water added to batch

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and another specimen made, it will be found that the latter will contain much greater voids by reason of its agreeable consistency to catch and hold in its mass small air bubbles, along with water globules from clarification. Most of such additional voids will not be shown by absorption tests, and can only be closely approximated by weight.

To illustrate: Take some soap bubbles and enclose them in a moist granular mass, and offer agitation or compression, the dissipation is complete; then place some in the interior of a mass, the consistence of thin-pour, and try to remove them by tamping or compression. It will be found the seasoned specimen will contain them just the same, and though they may be broken up into smaller cells, their full volume will remain in the mass.

The voids created by the addition of surplus water is not the only nor the principal damage done by reason of this excess water. Perhaps a greater damage is done by carrying with it, in suspension, particles of cement flour so important in the hardening process of other portions of the mass, which upon evaporation develop a lining to the cells almost impervious to moisture in an absorption tests.

There are very many things depending upon conditions when chemical action begins to take place in a mass of concrete. If the mass is highly porous, from excess of water, the crystals will be largely of needle shape, with hexagonal plates in the matrix films. If the mass is more dense, hexagonal plates and crystals will abound, and if the mass is of high density the bond will be hexagonal crystals planted in colloidal films. This last condition cannot exist if too much water is used in the mixture, unless much effort is used in tamping, or until an osmotic state is established in the mass.

The proper amount of water is the amount nearest to, without developing, clarification, and will vary with absorbing capacity of ingredients. Water-tamped concrete should not be used for street pavement.

CONTRACTION.

Expansion is neglible if contraction be properly provided for, since expansion comes from only one cause, that of rise of temperature (and absorption in porous concrete, which should not

be used in pavement), while *contraction* comes from several causes, some of which begin to operate almost immediately after the concrete is put in place, as follows:

(*a*) *Settlement* during moments of clarification (if such) which may lessen stress between solids.

(*b*) *Shrinkage* during drainage period (if any) which may open lines for percolation.

(*c*) *Shrinkage* after initial set has taken place. This form of contraction is probably the most damaging to concrete and is greatest in porous concretes, doing damage in the form of unseen cracks that develop later, leading one to mistake them for those of more recent origin.

(*d*) *Crystallization.*—Crystal and colloidal bonds like many other formations grow less as they grow older and stronger. This is another form of contraction that goes on for several months; in connection with this it will be understood that where moisture remains in the mass, these bonds may grow stronger without losing in size, and in the end will make a stronger bond.

It, therefore, becomes important that as much as possible of the original moisture be kept in the mass and as long as possible. Water sprinkled upon the surface of a too rapidly drying pavement will not answer, as such water soon vaporizes and rises in the air. More concrete is permanently damaged by this form of contraction by shrinkage, caused by too quick drying-out, and the cutting short of the hydration of the elements, than from poor material and mix.

SUB-GRADE.

It is seldom that an engineer objects to the amount of rolling of sub-grade, except to get as much as possible, claiming it is impossible to get too much.

More pavement is damaged by over-compression of the sub-grade than by under-filling. If a sample of earth be removed and subjected to great pressure and again placed in the earth and after a time be excavated, it will be found that this sample has restored itself to the natural density, or at least to that of the earth surrounding it. Uneven compression of the sub-base is responsible for much damage, commonly called "buckling of

pavement" at center or quarter. It is seldom an action of the pavement, but is caused by a raising up of pavement at points where over-compression exists in the sub-soil. The over-compression is highest at the center, since this is the easiest place to operate the roller, there being less liability of getting into the curb and gutter in the case of streets, and off in the ditch in the case of roads. Transverse cracks are often started by some form of shrinkage and extend when the sub-grade brings the restitution of its volume back to nature.

All clays are highly compressible—some of those on which tests were made restored themselves in one year, some in two, others in three or more, but all of them reverted to their natural volume in due course of time.

Where a soil is easily compressed, this should be done with caution, and in the reverse case, it usually gets little compression.

PROTECTION.

Concrete may be able to carry a great load at the age of one month, but will not resist the abrasive action of traffic. When one stone is displaced, the impact is multiplied upon its neighbor. Surface stones should be protected from actual contact with abrasion of traffic for a period of some months.

This is made practical by the placing of a surface coating in the right manner at the right time, and is well worth the small cost.

MAINTENANCE.

Slight variations in the grade of any pavement should receive immediate attention, as small defects will in a short time develop great damage.

REINFORCED CONCRETE PAVEMENTS AND ROADWAYS.

By B. S. Pease.*

The subject of Reinforced Concrete Pavements and Roadways should receive especial attention from consulting engineers, contractors, city officials and taxpayers for two main reasons. *First*, very little if any information up to the present time has been printed regarding this type of pavement either by the press, the engineering periodicals, or by local or national societies, and therefore full realization is given to the prospect of and the necessity for careful study and criticism of the opinions here expressed. *Second*, the actual necessity for the use of reinforcement in concrete pavements in order to secure the proper results under varying conditions.

The subject of plain concrete pavements has been very carefully studied and the results of actual construction have received due consideration. It has been definitely shown that a pavement with a concrete wearing surface is low in first cost, gives but slight resistance to traffic, affords a good foothold even on grades up to 8 per cent, and its sanitary qualities and favorableness to traffic are of the highest quality. As to its maintenance cost, the limited experience shows that it is lower than any other type of pavement surface. As stated previously, a great deal of thought and discussion has been given to this form of a wearing surface for street and roadway pavements with the result that a decision has been reached as to the proper mixture, manner of mixing, quality of materials and methods of handling the same. There has been, however, a universal knowledge that there is one great objection to this material and that is, the natural tendency for the formation of cracks.

Assuming the proper mixture, construction, etc., there are three main causes for crack formation, namely, poor foundation, contraction during the setting period, and expansion due to temperature changes. The proper methods for improving the

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foundation are now standardized, but many times there are local conditions that make it impossible to follow such standards. In other words, the soil itself, either for natural or artificial reasons, may be of such poor quality that it is impossible to secure the proper results by any of these methods. The question then is, assuming this poor foundation, how to properly construct the pavement so that good results may be obtained.

It has been definitely shown that concrete will contract during the setting period, the amount depending upon the presence of moisture, the proportion of the mixture, and the temperature. It is the custom in specifications to state that the foundation shall be sprinkled prior to the depositing of the concrete so that the water in the mixture will not be absorbed by the soil. This is undoubtedly a very good precaution, but at the same time it does not absolutely prevent a loss of the water in the concrete. If this loss should be sufficient to reduce the amount of water below what is necessary to produce hardening by uniting with the cement, the finished construction is undoubtedly weakened; but in any event the less the amount of water, the greater is the amount of contraction. The results of tests show an average decrease in volume during the setting period approximately equivalent to a change due to a variation of 100 deg. of temperature. It is not necessary to argue the point regarding the change in volume due to temperature changes, it being only necessary to mention that such changes do occur.

Assuming that cracks do form in the concrete surface, what are the effects? Cracks formed by contraction will fill with dirt, grit, or other non-compressible material and prevent expansion at a later time when such expansion is necessitated by an increase in temperature. Therefore the beneficial effect of pre-constructed expansion joints will be minimized; in fact this effect may be sufficient to entirely destroy the possibility of expansion.

The study that has been given to the proper construction of expansion joints shows that such joints must be protected to prevent the wearing away of these sharp and brittle edges by the action of wheel loads and horses' hoofs. If it is proper to say that the artificial joints will early show wear, is it not as proper to say that the same results will follow for those joints that have been naturally formed due to natural causes? The final effect of these

cracks in addition to their being disagreeable to ride over and to their unsightliness, will be to very materially decrease the life of the pavement.

The next question to consider is how to prevent the formation of cracks in concrete pavements. Some have tried the plan of building the pavement in small units with expansion or contraction joints, but experience has shown that this method is expensive, unsightly and not durable. It has been conceded by those familiar with this construction that the joint even when properly protected by means of steel plates is the weak portion of the wearing surface and that it is here where the surface will first break down and show deterioration. Another means of prevention or rather a means of taking care of cracks that have formed is to fill them with an asphalt preparation, the object being to prevent sand or other hard substances from entering the joint and, in addition, to give at least a partial support to the sharp brittle edges. This method requires a certain amount of expense, the protection to the edge of the joint is questionable, and the result is unsightly, at least for city pavements.

The more recent method for the prevention of cracks is to use reinforcement of a sufficient amount and properly placed, depending upon the conditions. So far as can be determined reinforcement was first used in a concrete street pavement in 1910, and the results obtained since then certainly warrant consideration by those interested, which is the case as shown by the rapid increase in the number of municipalities that have constructed pavements of this type. An examination of available records will show that in 1910 two municipalities in one state used reinforcement in their concrete pavement, while in 1913 at least 56 municipalities in 15 different states contained construction of this type. One and two-course construction has been used in about equal proportions.

In regard to the necessity for and the effect of the use of reinforcement, consider those pavements that will be laid on a foundation of questionable quality. The necessity for the use of a reinforcement to give structural strength to the slab is evident regardless of whether such foundation is poor in spots or whether the entire area shows unsatisfactory conditions. If the foundation consists of filled material, it is almost impossible even by the use of a heavy road roller to secure a foundation that will not

settle at some future date. As it is impossible to determine how much and where such settlement will take place, the logical suggestion is to use reinforcement so that the pavement will act as a unit and in this way prevent the formation of the destructive cracks.

An excellent example of this class of work is shown by the reinforced concrete pavement constructed in Oakland, Cal., on a street parallel to the United States Bulkhead and Estuary, and the following is a partial description of this work, given by the Syndicate Magazine, Oakland, Cal., under date of February, 1913:

> One of the most difficult engineering problems that has presented itself to the Board of Public Works has been the construction of a street giving access between the piers and various business concerns adjacent to the made ground. The unstable foundation which has not yet dried out, afforded but little more than a spongy mass as a road basis. When it is considered that these streets must be suitable for hauling heavy machinery, possibly 10 tons to the load, the character of the problem is evident. The necessity for permanent construction rejected the idea of a corduroy road of wood and the soft character of the foundation made macadam totally unsuitable for the heavy traffic. It was finally decided to lay a 6-in. concrete slab reinforced near the bottom with a steel wire mesh. Upon especially soft spots a second thickness of the wire fabric was laid at right angles to the other. This reinforced roadway is giving good service and bids fair to solve one of the greatest problems of road building.

If it is impossible to properly drain the foundation, thus allowing accumulation of moisture, the results will be disastrous if no reinforcement is used. During a rainy period water will accumulate near the outer edges, the pavement will settle under traffic loads because of this softened condition and cracks will form first in the top surface. During freezing weather the soil will expand because of the presence of the water, thus raising the outer edge and causing cracks to form at the lower side of the slab, and to prevent these cracks reinforcement should be placed as near to the bottom as possible and yet secure sufficient protection to prevent rusting.

This latter condition, however, is one that can and should be guarded against by proper drainage, and it is not the intention to advocate the use of reinforcement to take the place of proper drainage when such construction is possible. Therefore the only logical reason for placing the reinforcement at the bottom of the slab is to add structural strength to the slab placed over filled

ground that cannot be properly compacted by methods that are or should be familiar to all engineers.

In the construction of country roads the width will usually be such that a part of the metal will extend outside of the old beaten track and therefore the foundation will be more compact under the center portion, even if the center be scarified and re-rolled it will be almost impossible to secure a uniform result. This condition in itself will allow a settlement at the outer edges and cracks will form longitudinally unless suitable reinforcement is used near the top of the pavement.

Owing to the absence of sufficient strength in the concrete during the setting period, it is impossible to conceive how a movement of the pavement over the foundation because of the contraction of the setting cement is to be accomplished. This being the case the assumption naturally is that the concrete contains thousands of invisible cracks which will decrease its strength unless a reinforcement is included to prevent such cracks from opening up to any extent. When a pavement contracts because of a reduction in temperature, cracks will form at more or less regular intervals, the distance between such cracks depending upon the tensile strength of the concrete. It is for this reason that many engineers advocate a certain definite and close spacing of expansion joints. At the same time they concede that these joints are the weak spots in the pavement; therefore if some other method of construction could be used so that the number of these joints can be reduced, such a method should receive consideration. As concrete in itself has no dependable tensile strength, it is necessary to include a reinforcement to supply this deficiency. For several reasons the practice has been to place this reinforcement near the top of the slab.

For a two-course pavement the logical position is between the base and wearing courses where it will not only resist expansion and contraction of the entire slab but will also act as a connecting link between two bodies of concrete having a different mixture of the ingredients, and in addition it will prevent the formation of cracks along the crown of the pavement where experience shows cracks almost invariably form in pavements that are not reinforced.

For single-course work the reinforcement is usually placed

about two inches below the surface. Although this type is called single-course, it of necessity must be placed in two courses or layers in order to include the reinforcement.

The amount of reinforcement to use may vary with conditions, some of which must be determined by the engineer at the time, but a careful study of existing reinforced concrete pavements with special reference to the amount of reinforcement used shows that it is possible to specify the amount required in the average construction without knowing all the conditions. For country roads if the expansion joints are placed not to exceed 30 ft. centers, a reinforcement having a sectional area of metal of at least .049 sq. in. per ft. of width crosswise, and .038 sq. in. lengthwise of the pavement, will furnish sufficient resistance to prevent cracks due to shrinkage during setting, expansion or contraction from temperature changes, or to any ordinary inequality of the foundation soil.

The subject of proper spacing of expansion joints should be studied in connection with the reinforcement for the reason that the greater the spacing of joints the greater should be the amount of longitudinal reinforcing metal.

Past experience points to the fact that the principal change in the length of a concrete pavement is a contraction and although the metal has approximately the same coefficient of expansion as concrete and therefore will change in length about the same amount as the concrete, it will prevent the total shortening effect from being localized at definite intervals and will distribute the total change into innumerable small and invisible cracks that will not decrease the wearing qualities of the finished pavement. If the expansion joints are spaced at a greater distance than 30 ft. the amount of longitudinal reinforcement should be increased to at least 0.1 sq. in. per ft. width for spacing up to 100 ft. It is believed that by the addition of a sufficient amount of longitudinal reinforcement, it would be possible to construct the roadway without any expansion joints whatever.

For street pavements the early practice was to use a very light reinforcement, but the more recent ones have made use of a heavier material even for close spacing of expansion joints. In fact the tendency now is to increase the weight of reinforcement, and since this item is small in comparison to the total cost of the

finished work, it would appear to be poor economy to use a light material when for a slight additional expense a proper construction can be assured. The average cost for the reinforcement in place ready for concreting varies from $.07 to $.15 per sq. yd., depending upon the weight of reinforcement used. The same recommendations and the reasons therefor that have been given for necessary reinforcement for country roads will also apply to city pavement with the exception that regardless of the weight of reinforcement used, expansion joints will be required at all street and alley intersections or wherever connected with any permanent rigid construction.

In order that the reinforcement shall give the best results, the various members of which it is composed should be closely spaced so as to give a proper distribution of the metal. The metal should also have a high tensile strength and should be low in cost of installation.